(2)

USAFA TR 85-9

NUMBER OF TARGETS THREATENED SIMULTANEOUSLY (NOTTS) IN CONJUNCTION WITH OVER THE HORIZON BACK-SCATTER (OTHB) RADAR COVERAGE

JAMES F. SHEEDY, CAPTAIN, USAF

AUGUST 1985

FINAL REPORT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

DEAN OF THE FACULTY
UNITED STATES AIR FORCE ACADEMY
COLORADO SPRINGS, CO 80840

Technical Review by Lt Col Knepell
Department of Mathematical Sciences
USAF Academy, Colorado 80840

Technical Review by Lt Col William J. Riley
Department of Mathematical Sciences
USAF Academy, Colorado 80840

Editorial Review by Captain Hale
Department of English
USAF Academy, Colorado 80840

This research report is presented as a competent treatment of the subject, worthy of publication. The United States Air Force Academy vouches for the quality of the research, without necessarily endorsing the opinions and conclusions of the author.

This report has been cleared for open publication and/or public release by the appropriate Office of Information in accordance with AFM 190-1, AFR 12-30, and AFR 80-3. There is no objection to unlimited distribution of this report to the public at large, or by DDC to the National Technical Information Service.

This research report has been reviewed and is approved for publication.

Thomas E McCann

THOMAS E. McCANN, Lt Col, USAF
Director of Research and
Computer Based Education

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD-A159304

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE

3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for Public Release. Unlimited Distribution.

4. PERFORMING ORGANIZATION REPORT NUMBER(S)

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION: Dept of Mathematical Sciences

6b. OFFICE SYMBOL (If applicable): DFMS

7a. NAME OF MONITORING ORGANIZATION

6c. ADDRESS (City, State and ZIP Code): U.S. Air Force Academy, Colorado Springs, CO 80840-5811

7b. ADDRESS (City, State and ZIP Code)

8a. NAME OF FUNDING/SPONSORING ORGANIZATION

8b. OFFICE SYMBOL (If applicable)

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS (City, State and ZIP Code)

10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.

11. TITLE (Include Security Classification): Numbers of Targets Threatened Simultaneously in Conjunction with OTHB Radar Coverage

12. PERSONAL AUTHOR(S): JAMES F. SHEEDY, Capt, USAF

13a. TYPE OF REPORT: Final Report

13b. TIME COVERED: FROM Jan 84 TO Dec 85

14. DATE OF REPORT (Yr., Mo., Day): Aug ~~March~~ 1985

15. PAGE COUNT: 70

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB. GR.
12	02	
17	09	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number): Raid recognition, targets threatened simultaneously, bomber or cruise missile raid, background traffic, setting reaction thresholds and

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Number of Targets Threatened Simultaneously (NOTTS) is a measure of the presence (in a background of unknowns) of a surprise attack on the U.S. retaliatory force.

Four NOTTS indicators PEAK, KURTOSIS, RIDGE, and P1, P2 and P3 are defined and evaluated using the J5YA Raid Recognition Algorithm for a bomber or cruise missile raid against SAC and C^3 target sets. Scatter charts showing background noise produced by commercial traffic, raid plus noise combined are presented and used to describe the setting of reaction thresholds. The effect of time of day, probability of radar detection, and the choice of target set and raid design on reaction threshold are discussed.

Although ideal settings of indicators are practical in the cases discussed, attention is drawn to the limited data available for modeling of unknowns in OTHB coverage.

Keywords include!

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS ☐

21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL: JAMES F. SHEEDY, Capt, USAF

22b. TELEPHONE NUMBER (Include Area Code): (303) 472-3037

22c. OFFICE SYMBOL: DFMS

DD FORM 1473, 83 APR — EDITION OF 1 JAN 73 IS OBSOLETE.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

NUMBER OF TARGETS THREATENED SIMULTANEOUSLY (NOTTS)

IN CONJUNCTION WITH

OVER THE HORIZON BACK-SCATTER (OTHB)

RADAR COVERAGE

JAMES F. SHEEDY, CAPTAIN, USAF

UNITED STATES AIR FORCE ACADEMY, COLORADO

August ~~MAY~~ 1985

UNCLASSIFIED

ABSTRACT

Number of Targets Threatened Simultaneously (NOTTS) is a measure of the presence (in a background of unknowns) of a surprise attack on the U.S. retaliatory force.

Four NOTTS indicators PEAK, KURTOSIS, RIDGE, and P1,P2 and P3 are defined and evaluated using the J5YA Raid Recognition Algorithm for a bomber or cruise missile raid against SAC and C^3 target sets. Scatter charts showing background noise produced by commercial traffic, and raid plus noise combined are presented and used to describe the setting of reaction thresholds. The effect of time of day, probability of radar detection, and the choice of target set and raid design on reaction threshold are discussed.

Although ideal settings of indicators are practical in the cases discussed, attention is drawn to the limited data available for modeling of unknowns in OTHB coverage.

ACKNOWLEDGEMENTS

The raid recognition algorithm was a cooperative effort of individuals at Headquarters NORAD and the U.S. Air Force Academy. I wish to specifically thank Lt Colonel William J. Riley and Mr. Stuart B. Brown for their support and technical expertise in the area of raid recognition.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ACRONYMS

ASM - Air to Surface Missile

C^3 - Command, Control, and Communications

ERS - Experimental Radar System

FAA - Federal Aviation Administration

FATL - False Alarm Threshold Level

ICBM - Intercontinental Ballistic Missile

MOB - Main Operating Base

NCMC - NORAD Cheyenne Mountain Complex

NORAD - North American Aerospace Defense

NOTTS - Number of Targets Threatened Simultaneously

NWS - Northern Warning System

OASIS - Oceanic System Improvement Study

OTHB - Over the Horizon Back-Scatter

P_C - Probability of Classification

P_D - Probability of Detection

RDTL - Raid Detection Threshold Level

ROCC - Regional Operational Control Center

SAC - Strategic Air Command

ZULU - Greenwich Meridian Time

Number of Targets Threatened Simultaneously (NOTTS)
in conjunction with
Over the Horizon Back-Scatter (OTHB) Radar Coverage

I. PURPOSE

The purpose of this paper is to review progress in the development and evaluation of NOTTS raid recognition indicators.

II. THE PROBLEM

A missile attack on North America is deterred by the enemy's calculation of the damage to their homeland caused by the surviving U.S. retaliatory force.

A surprise attack on North America (if it were successful), could destroy Strategic Air Command (SAC) Main Operating Bases (MOBs), thereby removing SAC from the enemy's damage calculation. A surprise attack could also attack Command, Control, and Communications (C^3) sites required to launch land-based ICBMs, thereby delaying launch by perhaps half an hour. The land-based ICBMs can also become vulnerable to a missile attack and can be removed from the damage calculation, and destruction of C^3 sites may cause problems for the submarine arm, lowering calculated damage further. A surprise bomber or cruise missile attack reduces the deterrent against a missile attack.

The purpose of deterring a surprise bomber or cruise missile attack is to prevent the deterrent value of the Triad.

III. NOTTS FEATURE

A surprise attack must destroy its last target within a few minutes of the first target struck. Otherwise, the surprise attack fails since the destruction of the first targets provides tactical warning, which the attack aims to deny. Therefore, the number of targets which the surprise attack threatens nearly simultaneously, must be the full target set.

Consequently, if the means were available to detect aircraft approaching North America, an estimate of the number of key targets threatened simultaneously would show many targets threatened if these incoming aircraft or cruise missiles were participating in a surprise attack.

The acronym NOTTS represents the number of targets threatened simultaneously. A surprise attack need not have the NOTTS feature, but a surprise attack which affects the deterrent does.

Although an actual raid produces a large value of NOTTS, what about incoming commercial traffic? The large volume of commercial traffic creates a background of "noise", but this traffic was not designed to threaten North America, and hence should not generate significant NOTTS values.

IV. NOTTS INDICATORS

To shed some light on the value of the NOTTS feature in discriminating a bomber or cruise missile attack, several raid indicators based on NOTTS were defined.

PEAK

A NOTTS diagram is shown in Figure 1. This diagram presents the results of the evaluation of NOTTS for the NORAD data base of unknowns as it existed at 1200 hours. An unknown can reach one target at 1245 hours. Two unknowns can reach two targets simultaneously at 1300 hours. At 1400 hours NOTTS has a value of 4, and by 1500 hours NOTTS has dropped to 1.

The maximum height of this diagram will be called the PEAK indicator.

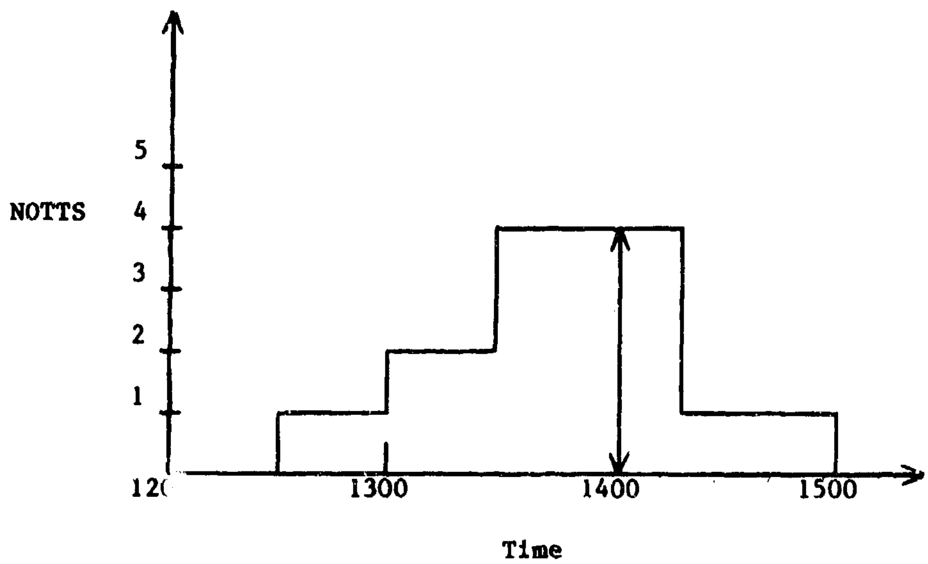


Figure 1
PEAK

KURTOSIS

The PEAK indicator will have the same value for either Figure 2a or 2b but Figure 2b has a more sharply defined spike. Therefore, KURTOSIS which measures the peakedness of the NOTTS diagram was introduced as a second NOTTS indicator. KURTOSIS uses the fourth moment about the origin as follows:

$$\text{KURTOSIS} = \frac{\mu_4}{\sigma^4}$$

where, $\mu_4 = \dfrac{\Sigma(Y - \mu)^4}{N}$

$\sigma^4 = (\sigma^2)^2$

Y = NOTTS value for each time period

μ = Mean of NOTTS over entire time period

N = Total NOTTS over entire time period

σ^2 = Variance of NOTTS

The KURTOSIS value for each NOTTS diagram was scaled by multiplying by the number of targets threatened for the entire diagram. The scaled KURTOSIS values, however, were small for more sharply defined spikes. Therefore, the reciprocal of the scaled KURTOSIS values were used as an indicator of peakedness since the reciprocal increases with more sharply defined spikes.

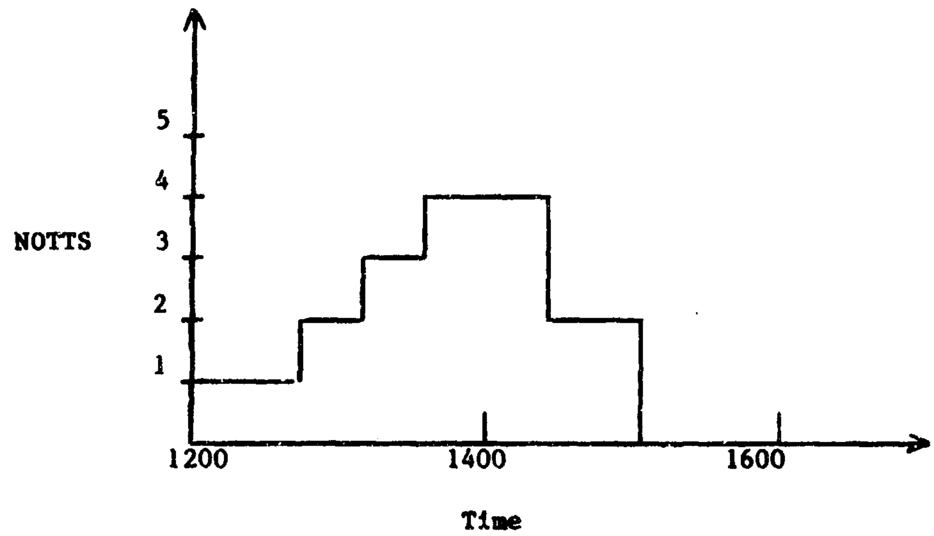


Figure 2a
Peakedness

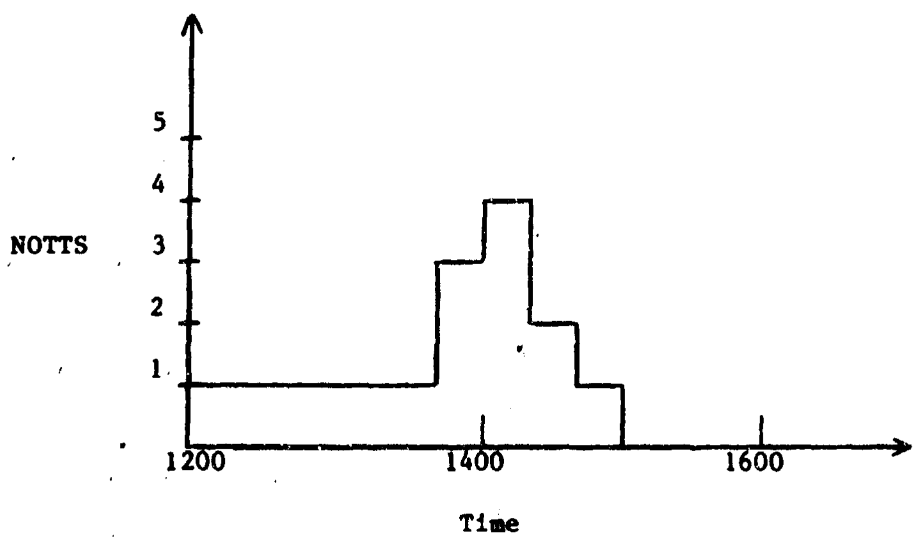


Figure 2b
Peakedness

RIDGE

A single NOTTS diagram is the latest in a series, and the PEAK and KURTOSIS indicators are obtained from the current NOTTS diagram. The third indicator called RIDGE summarizes a series of NOTTS diagrams. Figure 3b shows the latest NOTTS diagram, prepared at 1200 hours, and Figure 3a is the previous diagram, prepared at 1100 hours. RIDGE for 1230 hours is obtained by adding heights for this time (i.e., 1 + 6 + ...). In practice, ridges are calculated for each time interval on the current NOTTS diagram and the largest is chosen as the RIDGE indicator.

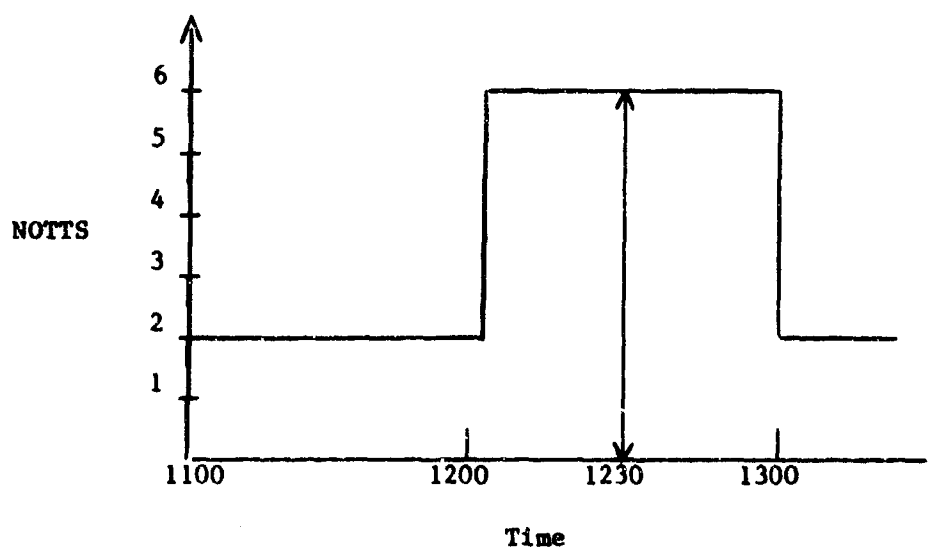


Figure 3a
RIDGE
(1100 hours)

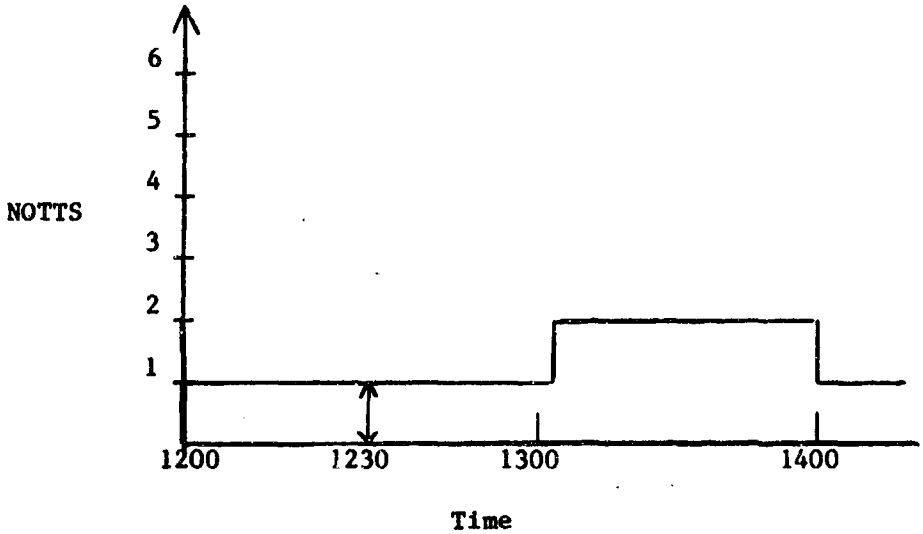


Figure 3b
RIDGE
(1200 hours)

P1, P2, and P3

The fourth indicators are the probabilities of a surprise attack being a 1 on 1, 2 on 1, or 3 on 1 raid. In other words, what is the probability that each target is being threatened by one, two, or three unknowns? These indicators are called P1, P2, and P3 and are calculated using a Chi-Square Goodness of Fit test which compares the number of unknowns threatening a target to the number expected to threaten a target if the raid were a 1 on 1, 2 on 1, or 3 on 1 attack. To illustrate, the following example shows 10 targets being threatened by either 0, 1, or 2 unknowns.

Unknowns Observed

Target #	Case I	Case II
1	0	2
2	0	1
3	1	2
4	1	2
5	0	1
6	1	0
7	1	1
8	2	2
9	1	2
10	1	1

Using the Chi-Square Goodness-of-Fit Test on Case I yields probabilities of approximately .90 and .10, for a 1 on 1 and 2 on 1 attack, respectively. Case II, however, yields probabilities of approximately .75 and .90. These results show that Case I is most likely a 1 on 1 attack, while Case II appears to be a 2 on 1 attack. The same data can be extended for a 3 on 1 raid. Although this methodology violates the assumption of an expected frequency of at least 2 in each class, it does give an indication of relative probability.

V. DEVELOPMENT OF DATA BASE OF UNKNOWNS

Evaluation of these indicators will be based on the current data base of unknowns at NORAD. This, in turn, will be based on reports from the Northern Warning System (NWS), the Over-the-Horizon Backscatter radar system (OTHB), and the Regional Operational Control Centers (ROCCs).

Since this data base does not yet exist, a method of constructing a data base was developed for this evaluation. The method provides a dynamic data base by simulating the air traffic on its' routes and reexamining positions every minute. Figure 4 shows the development of the data base and its' application by the raid recognition algorithm. In the example shown, a hostile raid and background commercial traffic are present.

Standard Raids and Targets

Figure 5a shows a raid design which consists of a standard 30 bomber raid against a standard target set consisting of 30 SAC and C^3 targets. The design provides for simultaneous impact using bombs against hard targets and deploying ASMs (along the dotted routes in Figure 5a) against soft targets.

Figure 5b depicts a raid design consisting of 34 cruise missiles launched from seven cruise missile carriers.

Figure 6 shows the number of raid tracks in NWS and OTHB coverage during the progress of the attack. One or more tracks are in coverage over a period of eight hours and approximately 20 for three hours.

Background Traffic

The commercial traffic includes 30 aircraft routes inbound from the east, which were extracted from the Federal Aviation Administration (FAA) sponsored Oceanic System Improvement (OASIS) Study. There are 369 tracks, and the number in OTHB coverage is shown in Figure 7. The hourly variation is extreme, reaching a peak of around 110 tracks at 1600 ZULU, and this variation suggests that reaction levels can be lowered during off-peak periods to provide more sensitivity in detecting raids during these periods.

In practice, background traffic will also include commercial traffic inbound from other directions. However, a good description of the latter has not yet been obtained.

Detection Probability and Classification

Returning to Figure 4, the first step in constructing the data base is to determine whether a given track is detected. One way to do this is to draw a random number for each track and to accept tracks whose random number is less than the detection probability. The detection probability will be provided to the NCMC (NORAD Cheyenne Mountain Complex) for each 7° sector of OTHB coverage. A system value can be obtained by (a) averaging sector values, (b) choosing the worst value, (c) weighting by sector raid probability, and (d) weighting by number of commercial flight plans. The system values studied are 0.90 and 0.50.

Once the detected tracks have been identified, the next step is to classify the tracks as known or unknown. Experience with the Experimental Radar System (ERS) indicates that 94% of detected commercial tracks were correlated with flight plans, leaving 6% of these as unknown. Again, random numbers were drawn to select the unknown commercial tracks.

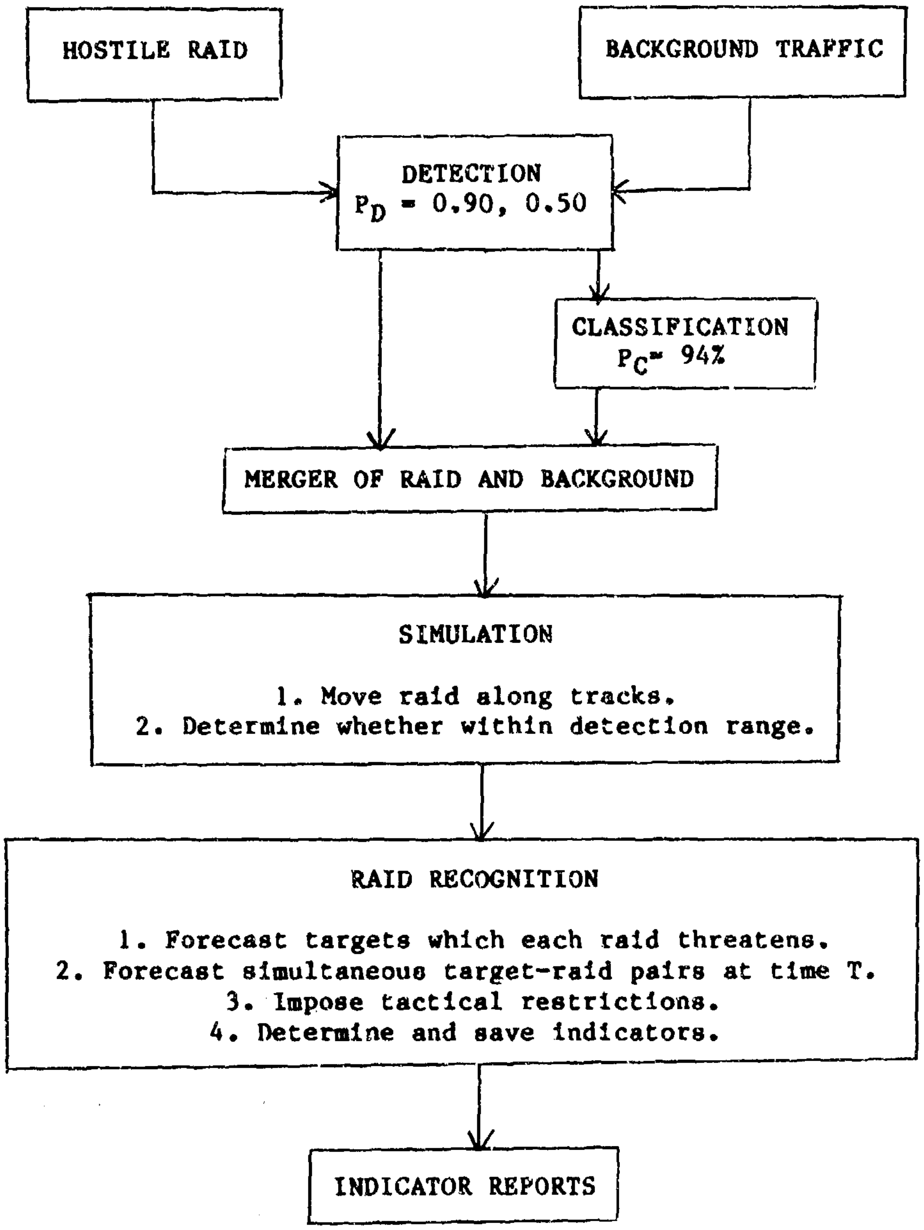


FIGURE 4

Evaluation of Indicators

Figure 5a
30 Bomber Raid

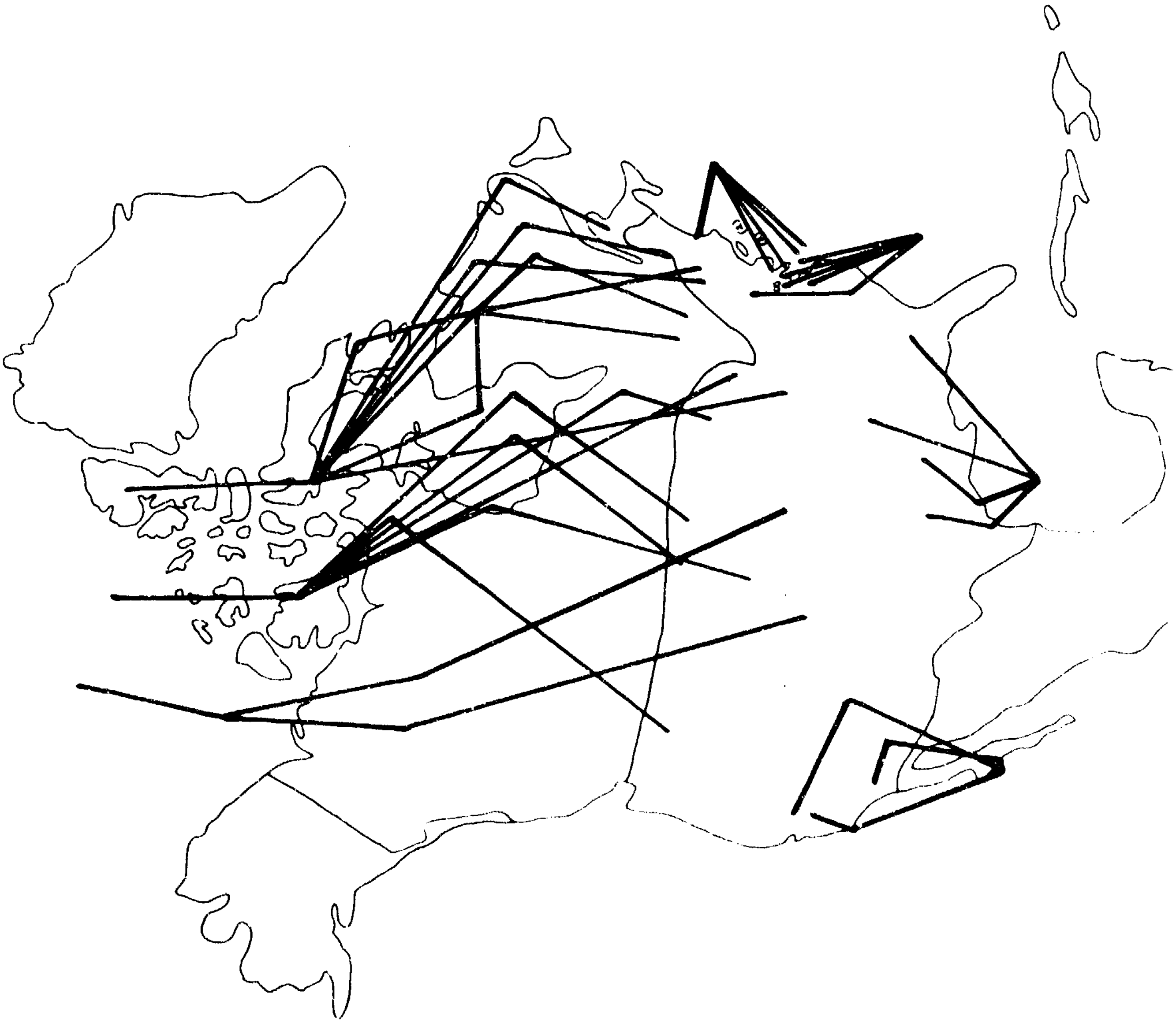


Figure 5b

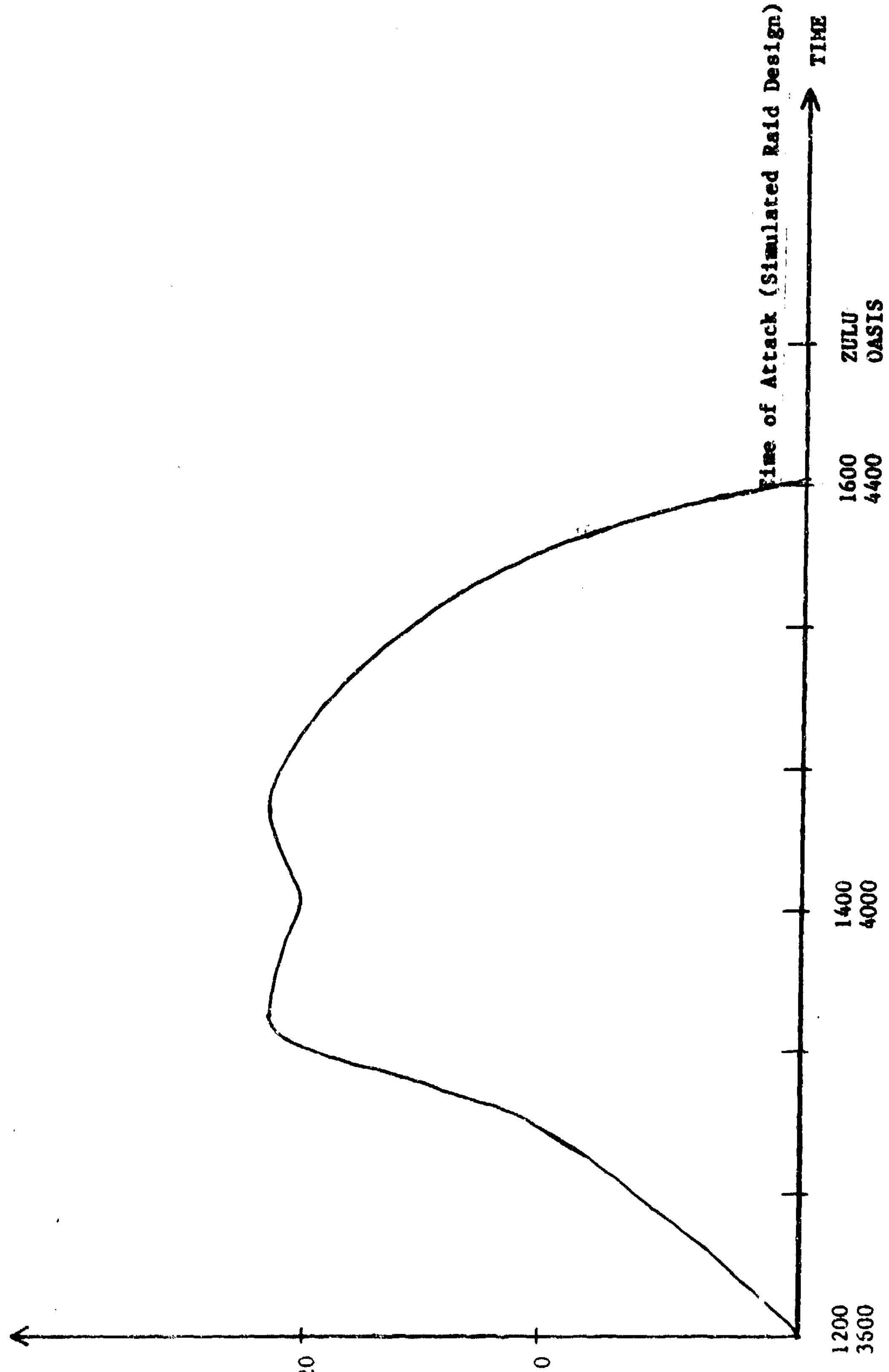


FIGURE 6
HOSTILE RAID IN COVER

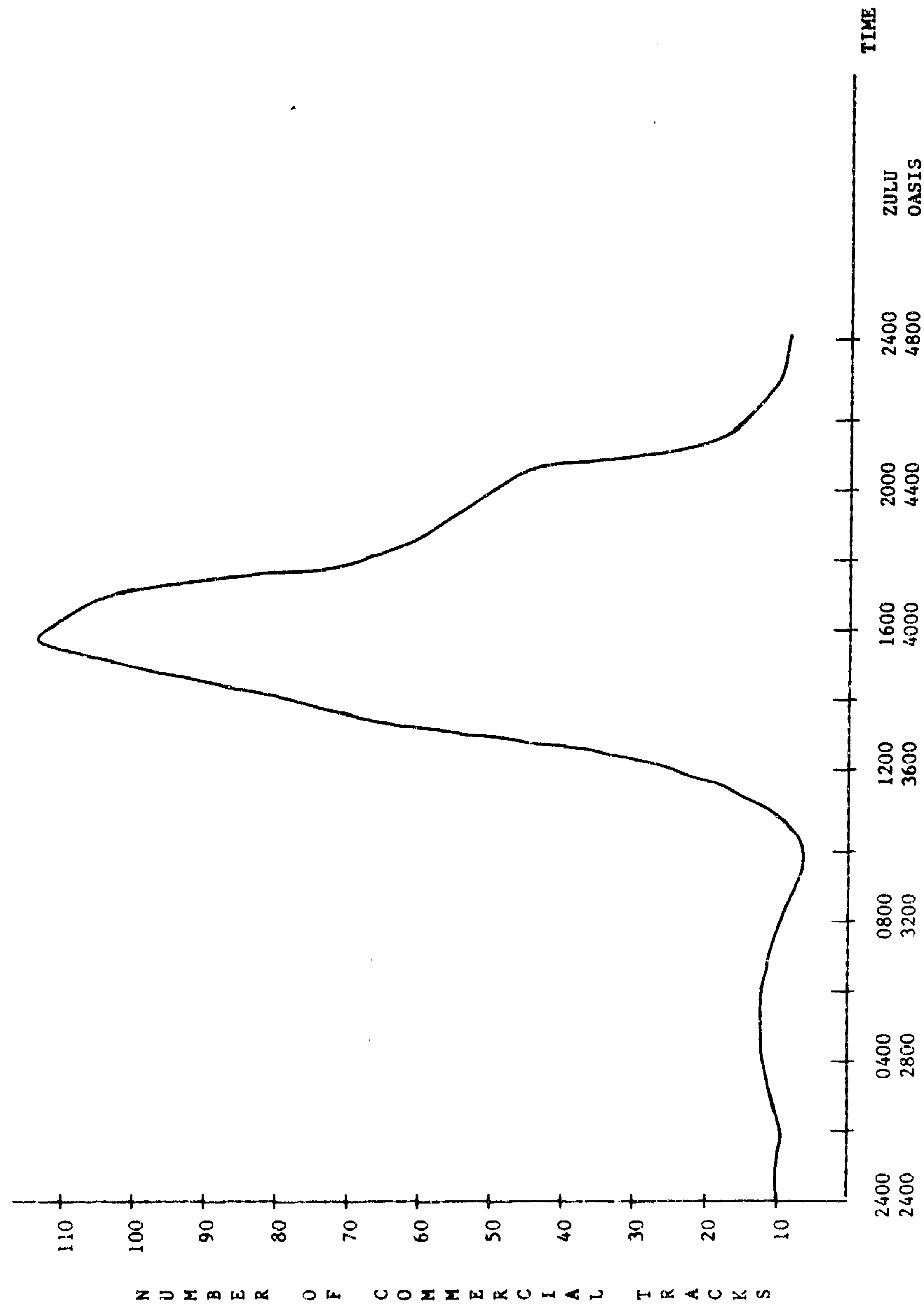


FIGURE 7
COMMERCIAL TRACKS IN COVER

Data Base

The timing of the bomber raid was phased to coincide with peak commercial traffic, which causes impact to occur at 2000 hours ZULU (4400 hours OASIS).

The cruise missile raid, however, was designed to have simultaneous impact of all cruise missiles at 4400 hours OASIS.

The simulation moves the unknown aircraft and cruise missiles along their respective tracks by one minute increments, and radar detection occurs when an aircraft or cruise missile enter radar cover (approximately 1700 nm for OTHB and 1480 nm for NWS). See Appendix B for a description of the OTHB and NWS radar coverages. The data base of unknowns was then augmented to include the new unknowns.

VI. RAID RECOGNITION ANALYSIS

Methodology

The raid recognition algorithm examines the data bank of unknowns every half hour.

Step 1

The first step shown in Figure 4 is to determine which target(s) each aircraft threatens, and time on target.

Forecast of Targets Threatened

The simple forecast, that each aircraft threatens all critical targets, is open to two modest refinements; (a) a threat cone, and (b) a maximum threat range. The latter can be used to prevent consideration of unlikely situations, such as an aircraft apprcaching the east coast targeted against a west coast target (or vice versa). The threat cone limits lateral movements after entering radar coverage. For example, an aircraft nearing the coast of Maine may not threaten southeastern targets.

Forecast of Time on Targets

Each of the bomber or cruise missile - target pairs obtained in the previous section is associated with a pair of times T1 and T2, the earliest and latest times, respectively, that the bomber or cruise missile can arrive at the target from its current position.

The earliest time of arrival is the distance of the geodesic line between each raid - target pair.

Later times of arrival may result from such factors as indirect routes (to avoid defenses) and lower speeds. The latest time of arrival is obtained as earliest time of arrival plus a tolerance which is proportional to the distance to the target.

Step 2

The second step is to identify which of the bombers or cruise missile - target pairs has the property that they can reach the target at a chosen future time T.

Since the earliest and latest times of arrival, T1 and T2, have already been determined for each pair, it is a simple matter to determine whether T is between T1 and T2 for each pair.

Step 3

The bomber or cruise missile - target pairs obtained in Step 2 may describe one bomber or cruise missile attacking several targets or one target being attacked by several bombers or cruise missiles. In the case of one bomber or cruise missile attacking several targets, it is necessary to discard all but one of the bomber or cruise missile - target pairs. This can be done in several ways. The algorithm of casting out pairs which is used in Step 3 maximizes NOTTS (the number of targets threatened simultaneously).

The number of targets reached at the future time T is now counted to establish a new point on the NOTTS diagram (ex., see Figure 1).

Step 4

Repetition of the foregoing, from the second step for each of several future times provides the points required to complete one NOTTS diagram. The NOTTS diagrams may then be examined to determine values for the NOTTS indicators (PEAK, KURTOSIS, RIDGE, P1, P2, and P3).

Parameter Settings

The raid recognition algorithm contains a number of parameters which must be set prior to carrying out an analysis. The effect(s) of these settings on the NOTTS indicator values were examined prior to the current study. Settings were chosen which yielded an effective analysis, and were held constant during the current study.

Scenarios

The scheme shown in Figure 4 was applied to collect indicator values under several situations, which are summarized in Figures 8 an 9. Each figure considers four main cases which treat two values of detection probability (P_D=.90 and P_D=.50) and two classes of target sets (the 30 standard targets and the 13 C^3 target subset of the 30). Figure 8, however, deals with a 30 bomber raid while Figure 9 deals with a 34 cruise missile raid .

	P_D = .90	P_D = .50
30 Targets Analyzed (SAC + C^3)	Background Alone Combined	Background Alone Combined
13 Targets Analyzed (C^3)	Background Alone Combined	Background Alone Combined

FIGURE 8
30 Bomber Raid

	P_D = .90	P_D = .50
30 Targets Analyzed (SAC + C^3)	Background Alone Combined	Background Alone Combined
13 Targets Analyzed (C^3)	Background Alone Combined	Background Alone Combined

FIGURE 9
Cruise Missile Raid

Background Effect

In each of these cases the first situation studied consisted of background commercial traffic alone (i.e., no hostile tracks were present). Five analyses, based on Figure 4 were carried out, and in each analysis 6% of the commercial tracks were chosen at random from 369 tracks and classified as unknown (i.e., uncorrelated with flight plans). Only five analyses were used due to computer time constraints, which produced five values of each indicator under background conditions.

Combined Effect

The second situation consisted of a raid in conjunction with background traffic. One analysis would suffice if $P_D = 1$ (since no random numbers occur in this case); when $P_D = .90$ or $.50$, five analyses were made. These calculations were repeated for each of the 8 main cases (Figures 8 and 9).

In the lower blocks 13 C^3 targets were analyzed, because although the raid is attacking 30 targets, it is not practical to guess the complete target set before evaluating the indicators. These cases will demonstrate the penalty, if any, in choosing to base the analysis on C^3 sites alone.

VII. RESULTS

Indicator Scatter Charts

Figure 10 shows results for the KURTOSIS indicator at two-hour intervals. The points marked by 'B' are the values with background traffic (i.e., noise) only. The variation in the values come from different random selections of tracks from the background traffic. The five combined cases (raid and background) are marked 'C'. Figure 10 contains all the values of the KURTOSIS indicator obtained for the upper left corner on Figure 8.

At time 35 (nine hours before impact) the KURTOSIS values are near noise level. Two hours later, the values are a little higher and at 41 hours they are well above noise level.

FIGURE 10
SCATTER PLOT-KURTOSIS
(P_D=.90, 30 Targets, 30 Bomber Raid)

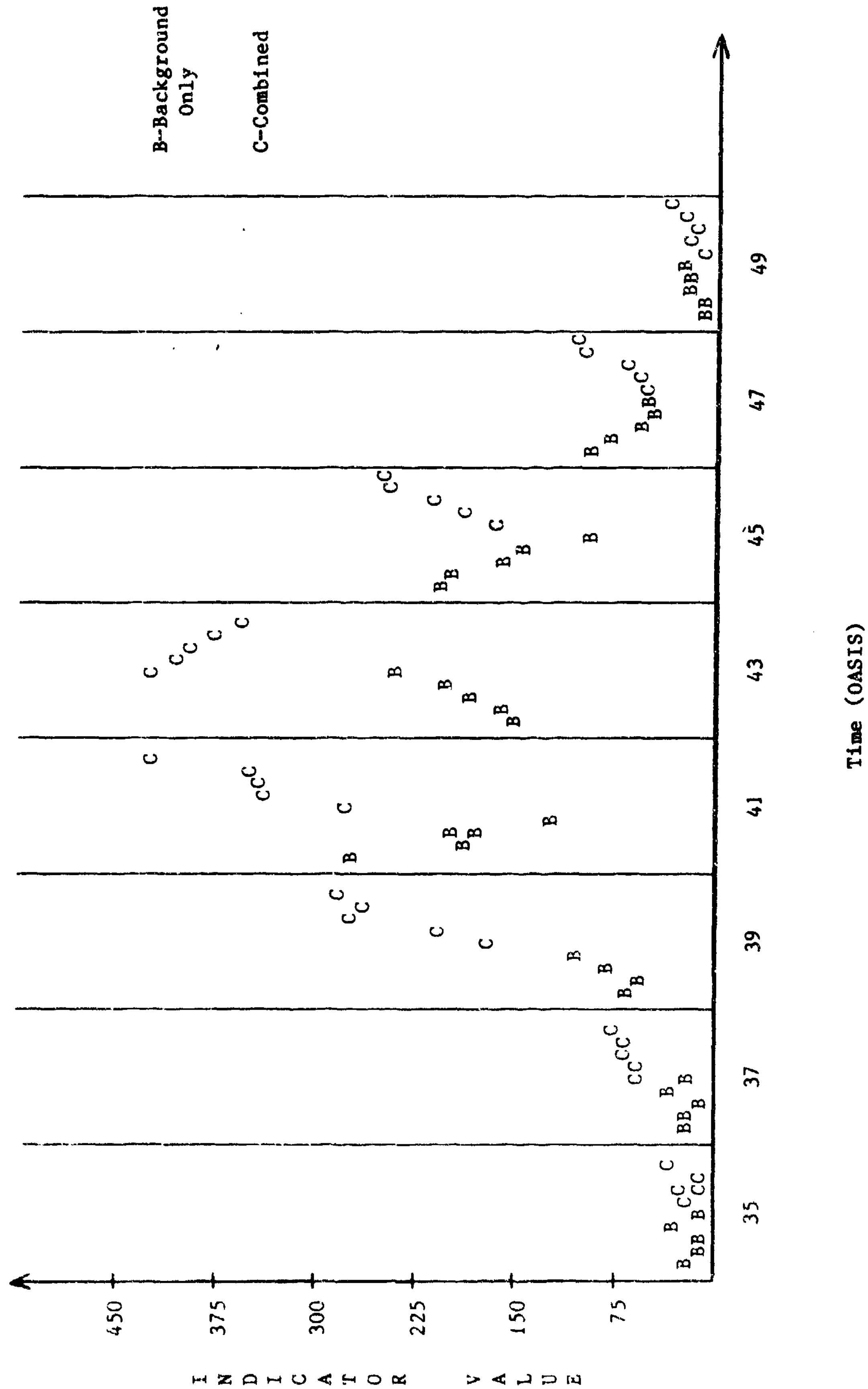


FIGURE 11
SCATTER PLOT-PEAK
(P_D=.90, 30 Targets, 30 Bomber Raid)

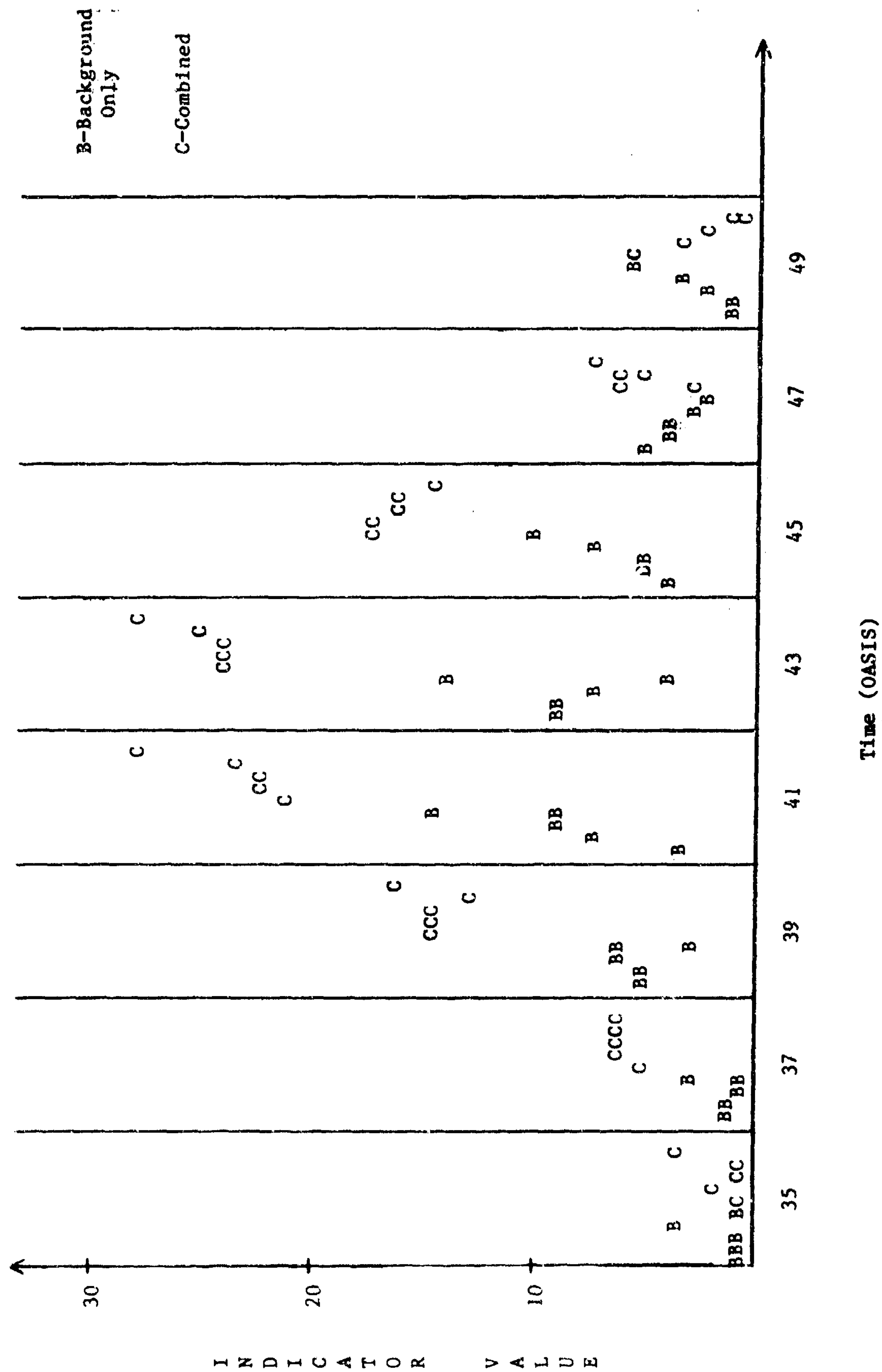


FIGURE 12
SCATTER PLOT-RIDGE
(P_D=.90, 30 Targets, 30 Bomber Raid)

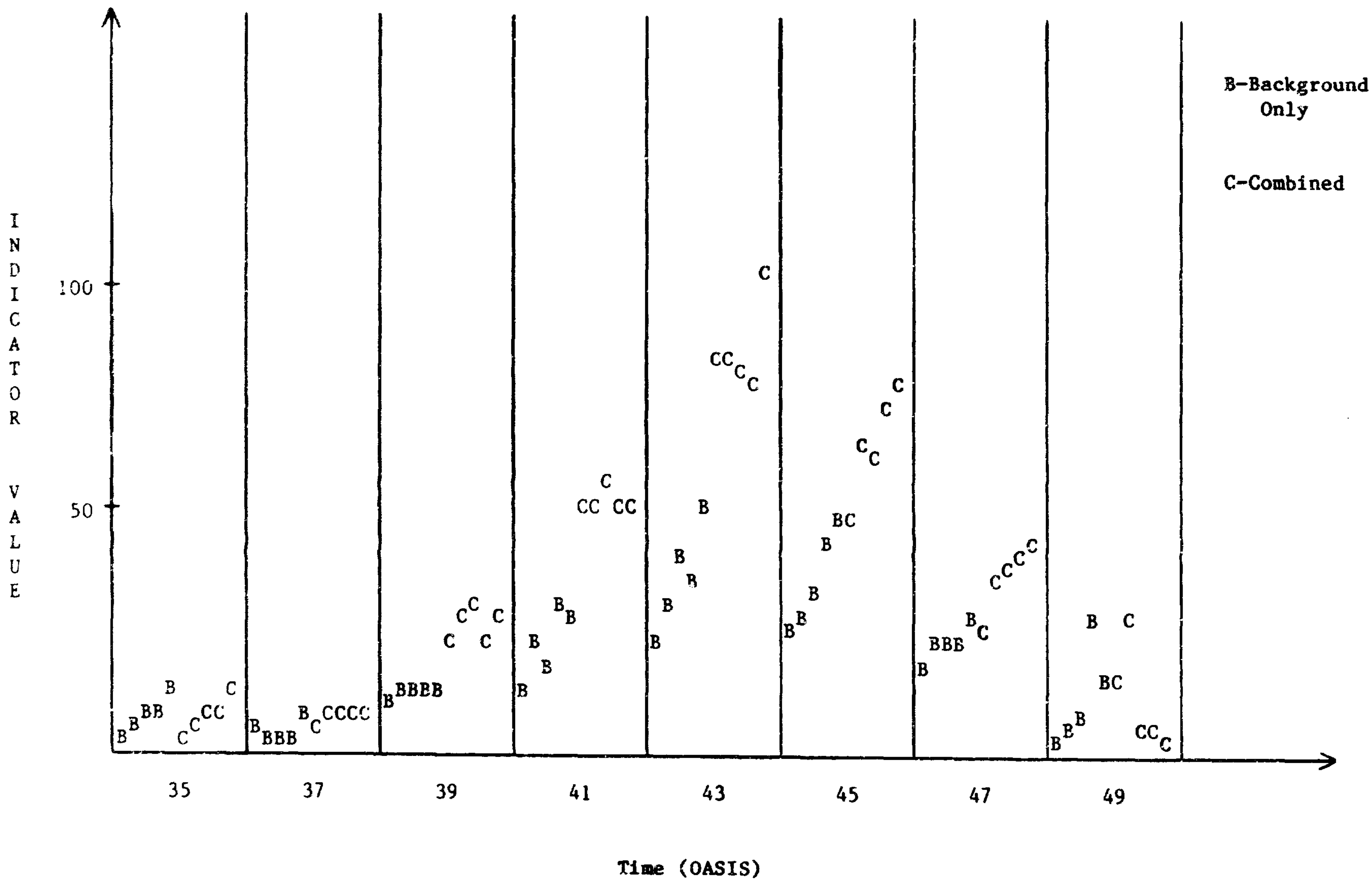


Figure 11 is a similar presentation of the PEAK indicator. The indicator is well above noise level at 39 hours and remains high, until impact at 44 hours, where twenty-seven of the thirty targets are indicated.

Figure 12 shows values of the RIDGE indicator. The combined values lie above background from time 39 to time of impact.

A complete set of these scatter diagrams is provided in Appendix A.

Summary Diagram (30 Bomber Raid)

Figure 13 gives a worst case summary of the scatter diagram results for the 30 bomber raid. The first two rows of Figure 13 identify the scenarios from Figure 8, and the raid indicators are shown in the first column. The triads given in the table are OASIS time, maximum background height at this time, and minimum value of combined height at this time. For example, the underlined entry for the PEAK indicator at OASIS time 43 shows that the highest noise level was 13 and the lowest value with the raid present was 24.

In Figure 13, all indicators (KURTOSIS, PEAK, AND RIDGE) do not mix raid and background at time 43. At time 41, however, all indicators are not 100% efficient in detecting a raid when one is present and not indicating a raid when one is absent.

TARGETS	30	30	13	13
P_D	.90	.50	.90	.50
KURTOSIS	43/253-353	43/165-209	43/120-143	43/74-93
PEAK	43/14-24	43/12-15	43/8-9	43/7-7
RIDGE	43/51-83	43/46-46	43/30-46	43/26-30
KURTOSIS	41/245-268	41/216-171	41/141-133	41/130-81
PEAK	41/15-20	41/12-12	41/10-11	41/7-5
RIDGE	41/25-48	41/23-28	41/17-32	41/14-19

FIGURE 13
Summary Diagram
(30 Bomber Raid)

Summary Diagram (Cruise Missile Raid)

Figure 14 gives a worst case summary of the scatter diagram results for the cruise missile raid, and as in the 30 Bomber Raid, the KURTOSIS and RIDGE indicators are not 100% efficient at time 41. The PEAK indicator, however, does not mix raid and background at time 41 or 43.

TARGETS	30	30	13	13
P_D	.90	.50	.90	.50
KURTOSIS	43/283-291	43/122-232	43/105-125	43/41-95
PEAK	43/13-15	43/7-11	43/7-13	43/3-7
RIDGE	43/55-47	43/30-38	43/28-44	43/13-23
KURTOSIS	41/257-252	41/130-127	41/146-112	41/42-44
PEAK	41/13-15	41/7-11	41/7-14	41/3-8
RIDGE	41/35-18	41/22-14	41/21-16	41/7-11

Figure 14
Summary Diagram
(Cruise Missile Raid)

Reaction Thresholds

When setting reaction thresholds, an interesting dilemma arises; are we more concerned with the probability of not detecting a raid when one is present, or the probability of a false alarm? If we're concerned with not detecting a raid when one is present, the reaction threshold should be set at the minimum combined level (Raid Detection Threshold Level -RDTL), which guarantees that a raid will always be detected, by any of the indicators, when one is present. But if we're concerned with false alarms, the reaction threshold should be set at the minimum background level +1 (False Alarm Threshold Level-FATL), which guarantees that a raid will never be indicated when none is present. A prudent person, however, would rather risk a false alarm then be caught unprepared for an actual raid; hence, RDTL is of greater concern.

Figures 15 and 16 present both concerns (raid detection and false alarm) for the 30 bomber and cruise missile raids at times 41 and 43. These times were chosen since both raids are designed to have simultaneous impact at time 44. The first two rows of Figures 15 and 16 identify the case from Figure 8, and the indicators are shown in the first column. The values given in the table are percent (%) of raids not detected and percent of false alarms using RDTL and FATL, respectively.

At time 41, all three indicators have major problems with both detecting a raid and reporting false alarms. These problems, however, are much less for reporting false alarms if we're concerned with raid detection, and as stated earlier, the risk of being unprepared outweighs the risk of false alarm.

By time 43, which is still one hour before impact, the KURTOSIS indicator no longer has problems with either raid detection or false alarm, PEAK has only minor problems when working with a smaller target set, and RIDGE appears to have only one problem with raid detection and false alarm for the 30 target set/P_D = .90 scenario. The RIDGE problem may be an outlier, and is reexamined in Appendix C.

TIME	TARGETS	30	30	13	13
	P_D	.90	.50	.90	.50
	KURTOSIS	0-0	0-0	0-0	0-0
4300	PEAK	0-0	0-0	0-20	20-20
	RIDGE	0-0	20-20	0-0	0-0
	KURTOSIS	0-0	60-20	20-20	60-40
4100	PEAK	0-0	20-20	20-20	20-60
	RIDGE	0-0	0-0	0-0	0-0

Figure 15
Reaction Thresholds
(30 Bomber Raid)

TIME	TARGETS	30	30	13	13
	P_D	.90	.50	.90	.50
	KURTOSIS	0-0	0-0	0-0	0-0
4300	PEAK	0-0	0-0	0-0	0-0
	RIDGE	100-40	0-0	0-0	0-0
	KURTOSIS	20-20	20-20	100-60	0-0
4100	PEAK	0-0	0-0	0-0	0-0
	RIDGE	100-60	80-40	100-40	0-0

Figure 16
Reaction Thresholds
(Cruise Missile Raid)

P1, P2, and P3 Results

Figures 17 and 18 provide the frequencies for the probability of a bomber or cruise missile raid being a 1 on 1, 2 on 1, or 3 on 1 attack. Since the bomber raid was designed to be a 1 on 1 attack, P1 should be greater than P2, which as shown in Figure 17 is the case.

Both the bomber and cruise missile raids indicate P2 values greater than zero, which means that there is the possibility of an attack being a 2 on 1. The P2 indicator, however, never overcomes the P1 indicator, which means that the either raid is most likely a 1 on 1 attack, but retains the "possibility" of being a 2 on 1 attack. The probability of either raid being a 3 on 1 attack is essentially zero.

Probability	P1 Frequency	P2 Frequency	P3 Frequency
$p=0$	0	0	30
$0<p<.20$	0	20	10
$.20\leq p<.40$	0	0	0
$.40\leq p<.60$	0	0	0
$.60\leq p<.80$	0	10	0
$.80\leq p<1.0$	30	20	0
$p=1.0$	10	0	0
	40	40	40

Figure 17
P1, P2, and P3 Frequency Chart
for 40 Simulations of a
30 Bomber Raid
(4300 hours OASIS)

Probability	P1 Frequency	P2 Frequency	P3 Frequency
$p=0$	0	21	40
$0<p<.10$	0	19	0
$.10\leq p<.20$	0	6	0
$.20\leq p<.30$	0	1	0
$.30\leq p<.40$	0	3	0
$.40\leq p<.50$	4	0	0
$.50\leq p<.60$	3	0	0
$.60\leq p<.70$	6	0	0
$.70\leq p<.80$	13	0	0
$.80\leq p<.90$	10	0	0
$p\geq.90$	4	0	0
	40	40	40

Figure 18
P1, P2, and P3 Frequency Chart
for 40 Simulations of a
34 Cruise Missile Raid
(4300 hours OASIS)

We must remember that all these probabilities are just relative measures, and should only be referred to when KURTOSIS, PEAK, or RIDGE indicate an imminent attack.

The Effect of Time on Threshold

The distribution of inbound commercial traffic shown in Figure 7 indicates a very uneven flow of traffic during a 24 hour period, with a strong peak at 1600-1700 hours ZULU. The effect of this uneven flow is to cause background values of the indicators to vary with time (as shown in Figures 10, 11, and 12).

Threshold values could be set as a constant value independent of time, but this would be a bad method since the setting would be too high off-peak. Hence, the use of different thresholds for peak and off-peak conditions will provide greater sensitivity. On the basis of this study, hourly settings over the period 1200-2000 hours ZULU appear better still.

The Effect of P_D on Threshold

Indicator values derived for P_D = .90 and .50 are shown in Figures 13 and 14. Using Figure 13 at time 43, the PEAK indicator has a value of 14 from background noise and a value of 24 for noise plus raid when P_D = .90 (30 target case). The corresponding values when P_D = .50 are 12 and 15. Since P_D is known, scaling the Raid Detection Threshold Level (RDTL) appears appropriate for both raid designs, using P_D and a proportionality constant.

The P_D value applied, however, is an average over all detection sectors. Various methods of forming this average are given in the section "Probability of Detection".

In practice, it may prove useful in meeting other requirements to set thresholds based on the number of unknowns in each detection sector. These will scale with P_D, but the subject of this paper is NOTTS for which a system value of P_D seems necessary.

The Effect of Target Set on Threshold

The two cases studied were the SAC and C^3 target set of 30, and the C^3 subset of 13 targets. In Figures 15 and 16, the first two and last two columns can be compared to examine this effect.

In general, a penalty is paid by restricting the analysis to a target subset, which was evidenced with the PEAK indicator. The penalty appears to consist of approximately the same background noise levels and a smaller raid signal.

In Figures 15 and 16 at time 43, except for the RIDGE indicator which may be an outlier, there is no difficulty in recognizing a raid in the 30 target situation. A reduction in the target set may cause difficulty, but this difficulty is avoided in this study because the signal is so strong for the 30 target case.

The Effect of Raid Design on Threshold

The two raid designs studied were the 30 bomber raid phased to coincide with peak commercial traffic, and the 34 cruise missile raid designed to have simultaneous impact at 4400 hours OASIS. The cruise missile raid design appears to have more problems than the bomber raid design, especially when concerned with false alarms. In fact, if false alarms have a higher priority than raid detection there are 4 cases in Figure 16 in which KURTOSIS and RIDGE do not detect an actual raid. The KURTOSIS problem doesn't appear to be a major problem since it is totally rectified by 4300 hours OASIS (1 hour before impact). The RIDGE problem, on the other hand, continues through 4300 hours under the high P_D case, and as stated earlier, appears to be an outlier and is reexamined in Appendix D.

The NOTTS indicators have more difficulty recognizing a raid when one is present and not indicating a raid when one is absent in the cruise missile case, than the bomber case. This appears to be caused by only 7 unknowns in radar coverage suddenly becoming 34 unknowns in the cruise missile case; while in the 30 bomber case all 30 are classified as unknowns as soon as they enter radar coverage. Due to this delay in the OTHB coverage recognizing the cruise missile raid, the NOTTS indicators do not exceed the reaction thresholds until one hour before impact (4400 hours OASIS); hence, the cruise missile raid is performing its' mission effectively.

VIII. LIMITATIONS

These results are the best obtainable at present, since limitations are unavoidable. Background commercial traffic may fluctuate more than indicated. The OTHB detection zone and tracking zone, the P_D values and correlation probability all correspond to examples of ERS experience. However, fluctuations are not well documented.

The possibility of cross-correlation between P_D and P_C is not documented and its consideration has been omitted.

Only five simulations of each case in Figures 8 and 9 were performed due to computer time constraints, and additional runs might have provided further insight into the setting of reaction thresholds.

P_D = .90 and .50 were the only detection probabilities examined, and other P_D's such as .70 could be evaluated.

Finally, it has been assumed that members of the bomber and cruise missile raids are classified as unknown. Yet the ocean flight plan registration is not secure.

IX. CONCLUSIONS

(1) Four indicators of the presence of a possible raid have been evaluated using a simulated data bank of unknowns and the J5YA raid recognition algorithm.

(2) The examples used in the evaluation were a 30 bomber raid phased to coincide with maximum (incoming) background traffic, and a 34 cruise missile raid designed to have simultaneous impact at 4400 hours OASIS.

(3) All four indicators; PEAK, KURTOSIS, RIDGE, and P1, P2, and P3 performed well for 4300 hours OASIS, which is one hour before impact.

(4) When presented with a choice between raid detection and false alarm as the primary concern, raid detection is the wise choice and the Raid Detection Threshold Level (RDTL) should be used. The values on the left side of Figures 15 and 16 indicate very low percentages of false alarm when RDTL is used, especially at 4300 hours OASIS and high P_D.

(5) Background and combined values of the indicators were determined for detection probabilities of .90 and .50, and for bomber and cruise missile raids.

(6) Effects of time of day, P_D, and target set on reaction threshold settings were discussed. Reaction threshold should vary with time of day, and scale proportionately with P_D value.

(7) Applications to small subsets of critical targets is not recommended since the background signal decreases more slowly than the raid plus background signal.

(8) The results of this study are necessarily preliminary in nature. Further information on the variability in background traffic and in detection and classification by OTHB is required.

X. RECOMMENDATIONS

(1) Analyze additional simulations of the cases outlined in Figures 8 and 9 to possibly obtain more accurate estimates of raid detection and false alarm using FATL and RDTL, respectively.

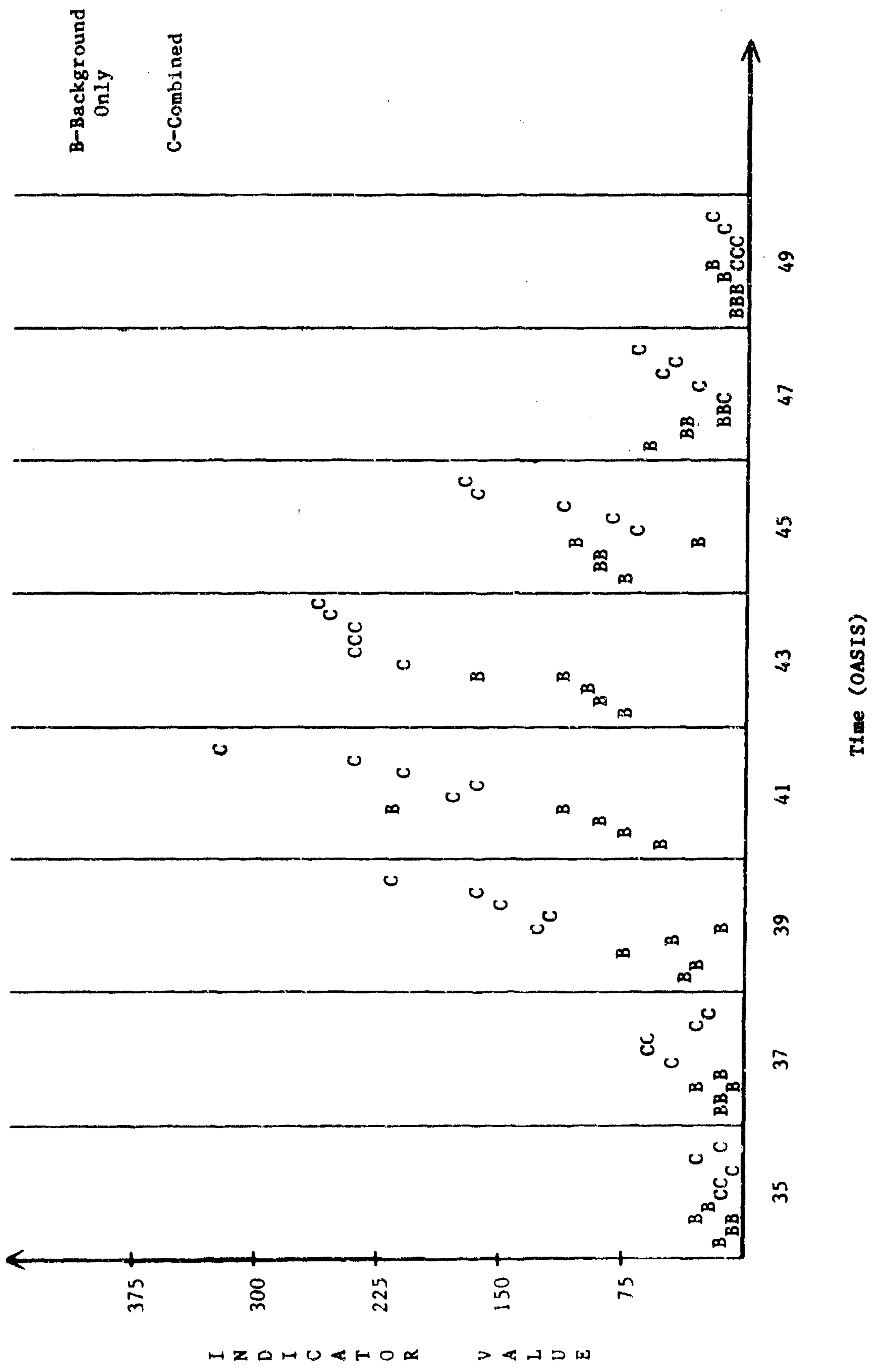
(2) Continue analysis, using different values of P_D, to evaluate the sensitivity of reaction thresholds to P_D.

(3) Obtain additional raid designs to further evaluate the effect of raid design on reaction thresholds.

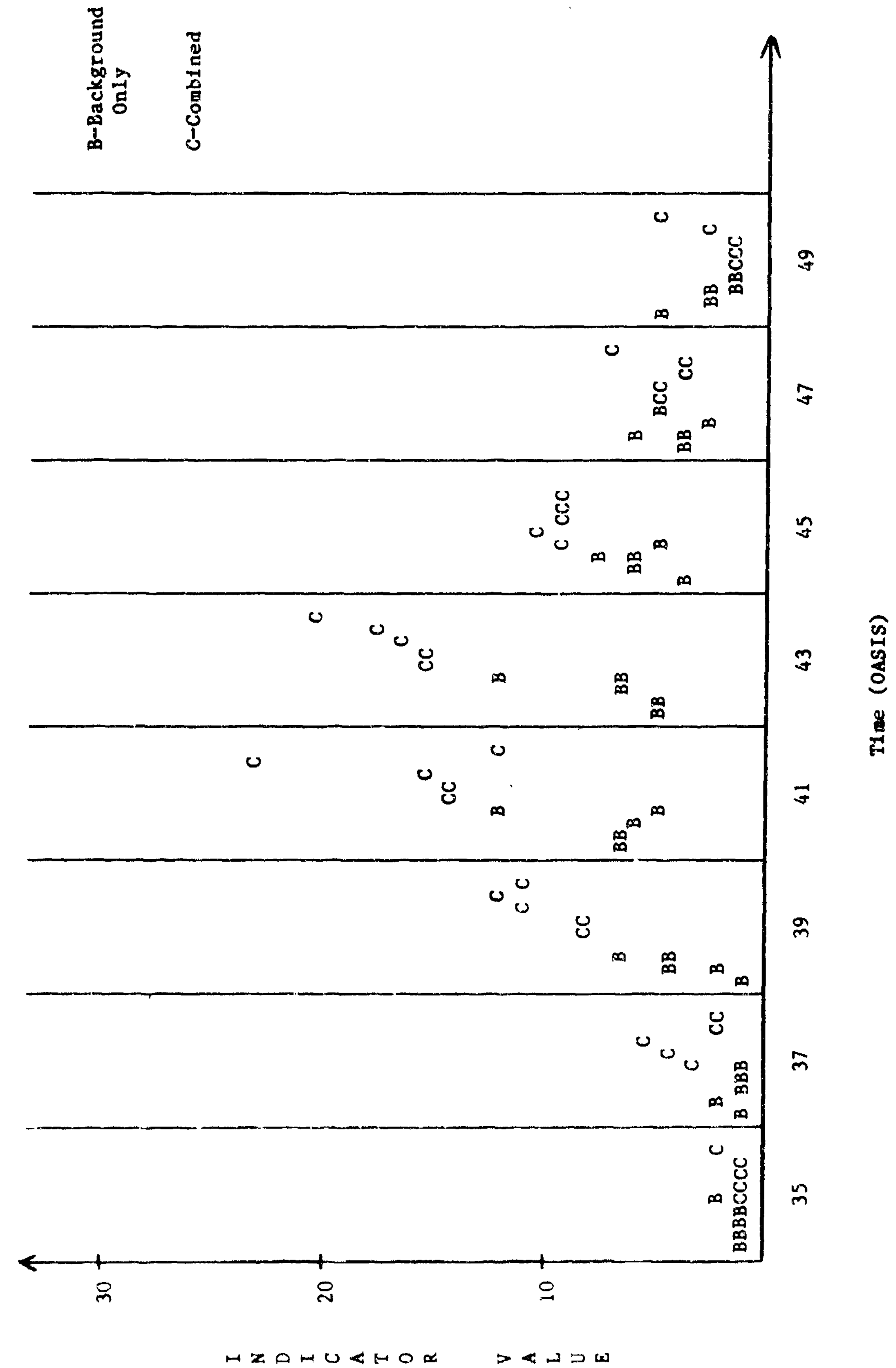
APPENDIX A

Additional Scatter Charts

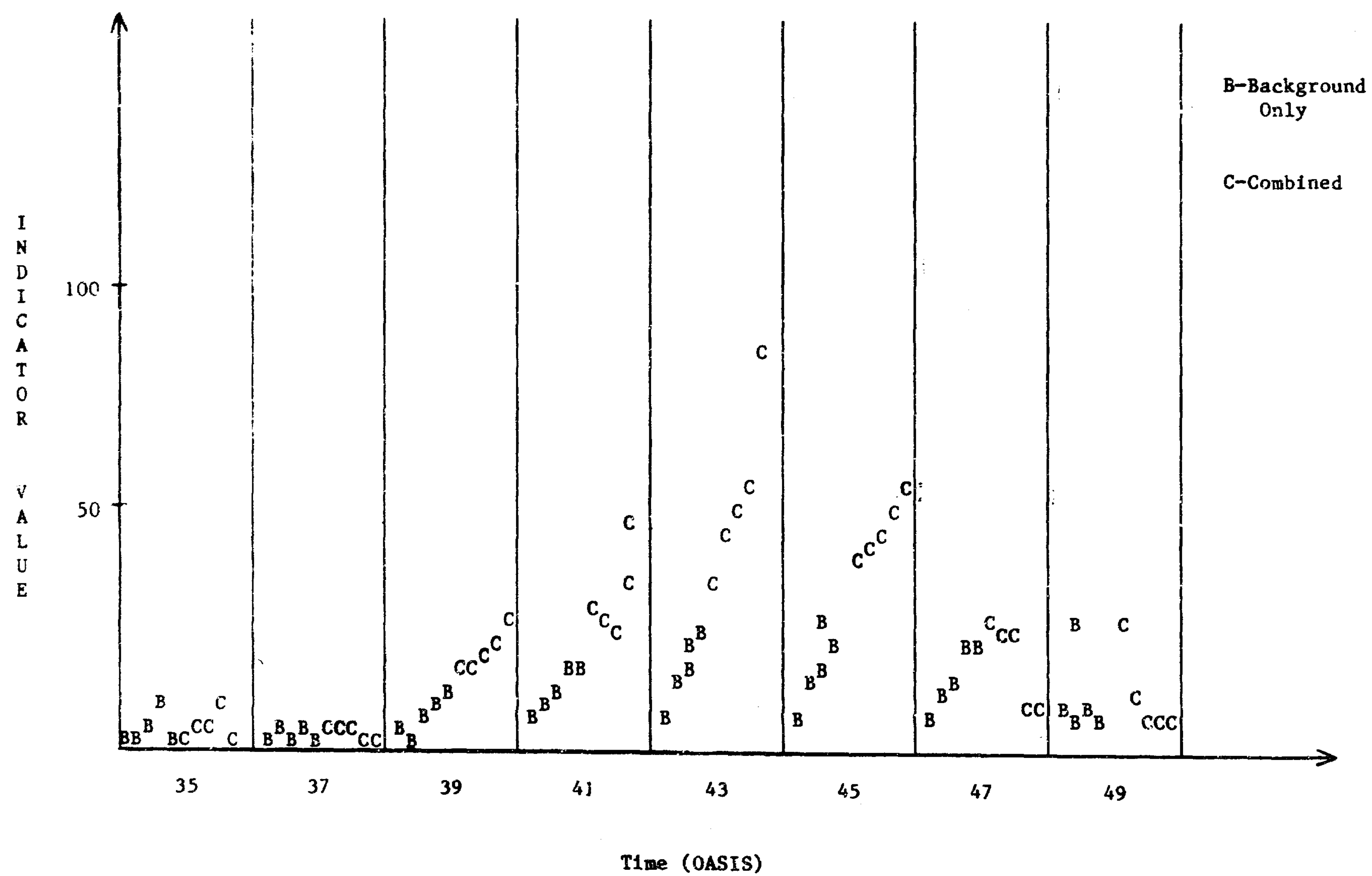
SCATTER PLOT-KURTOSIS
(P_D=.50, 30 Targets, 30 Bomber Raid)

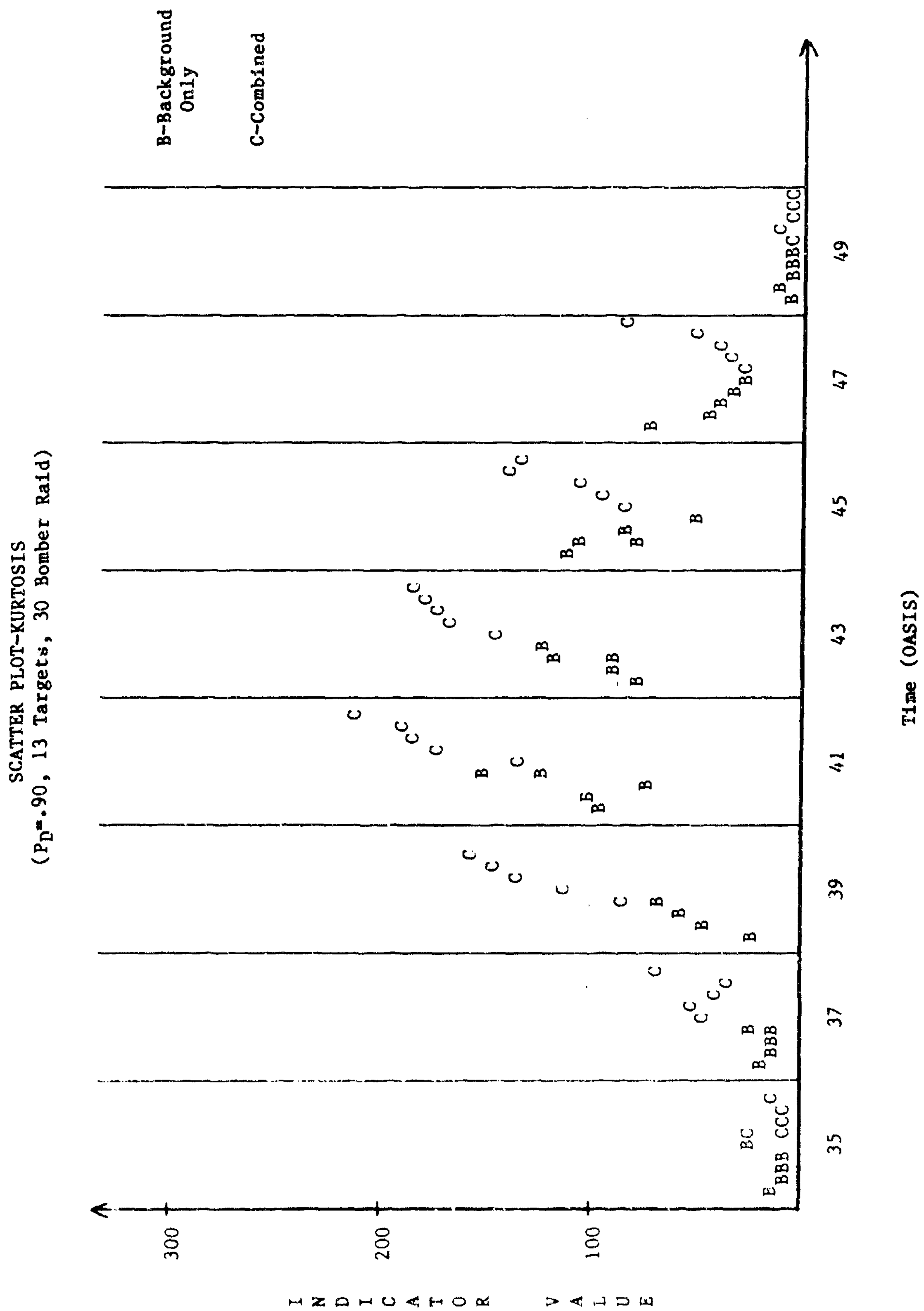


SCATTER PLOT--PEAK
(P_D=.50, 30 Targets, 30 Bomber Raid)

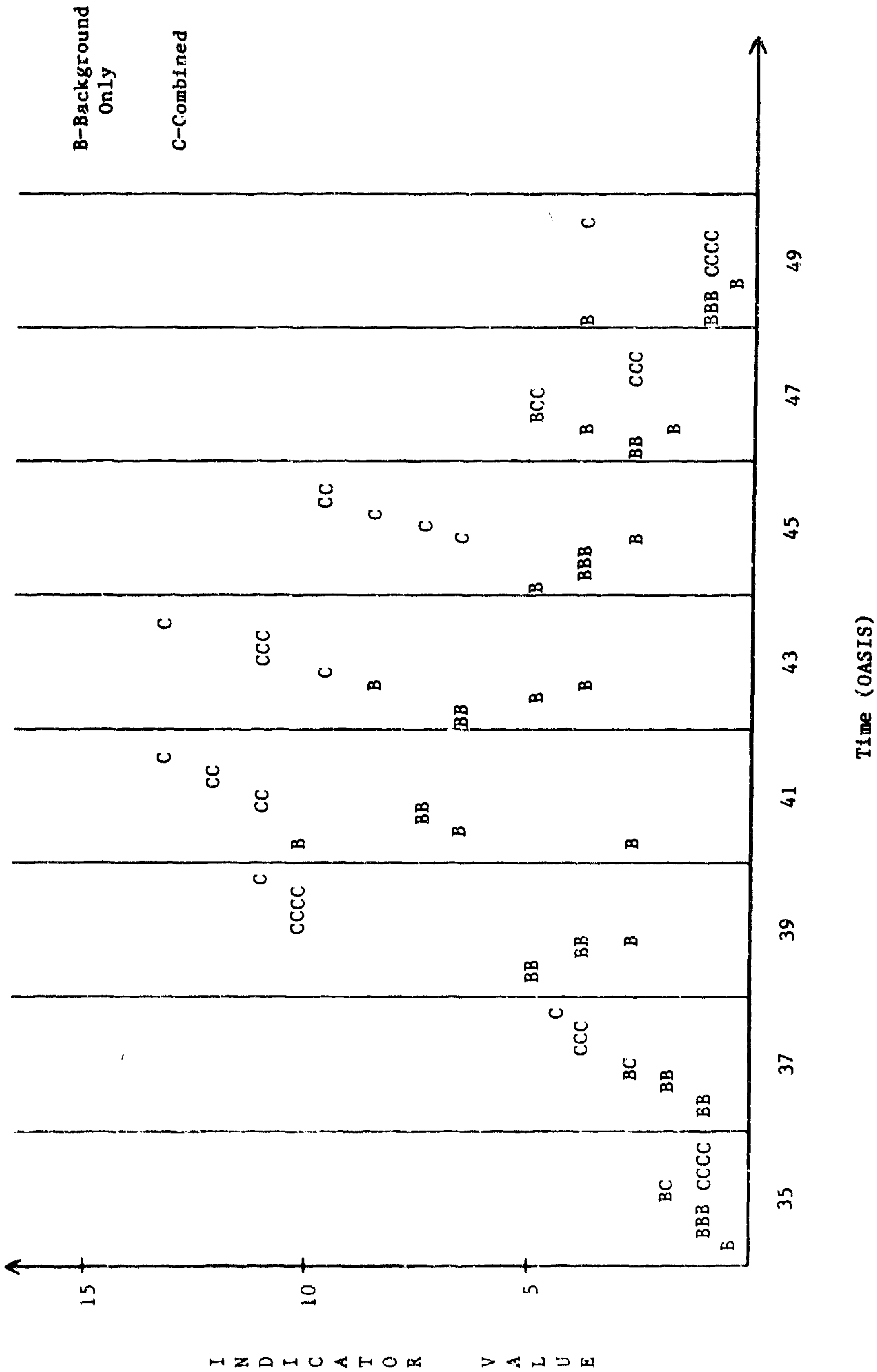


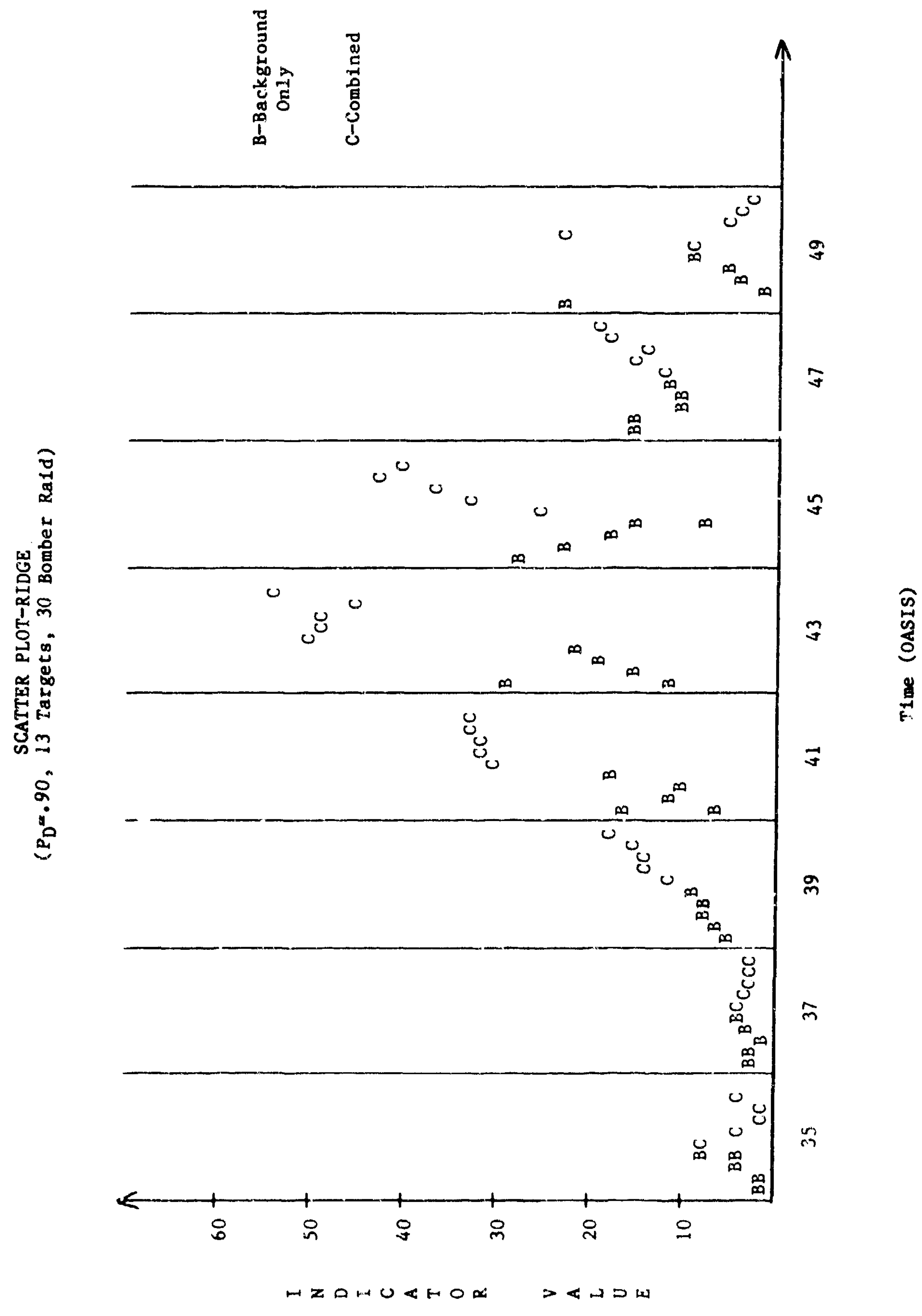
SCATTER PLOT-RIDGE
(P_D=.50, 30 Targets, 30 Bomber Raid)

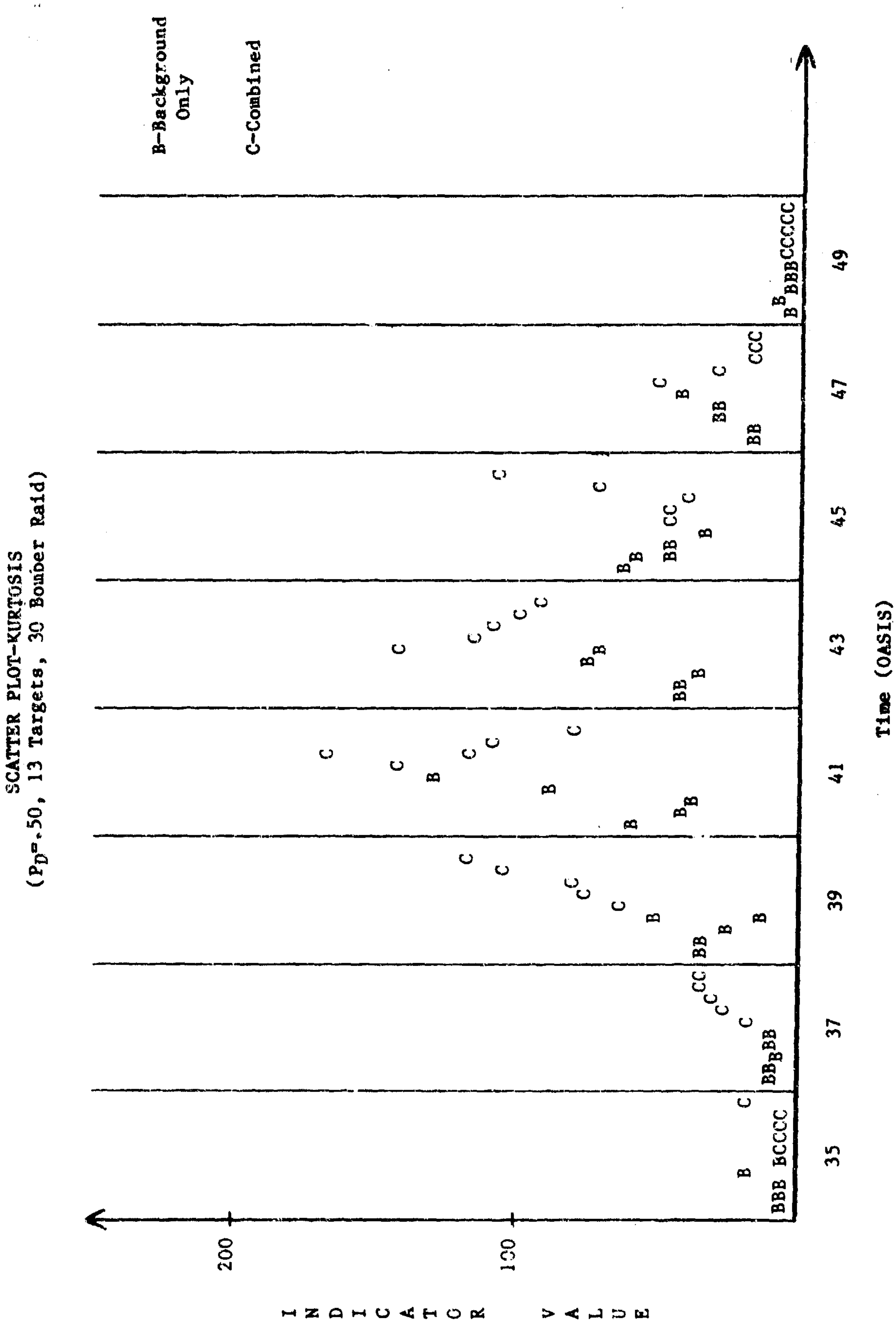



SCATTER PLOT-KURTOSIS
(P_D=.90, 13 Targets, 30 Bomber Raid)
B-Background Only
C-Combined
INDICATOR VALUE
300
200
100
Time (OASIS)
35
37
39
41
43
45
47
49

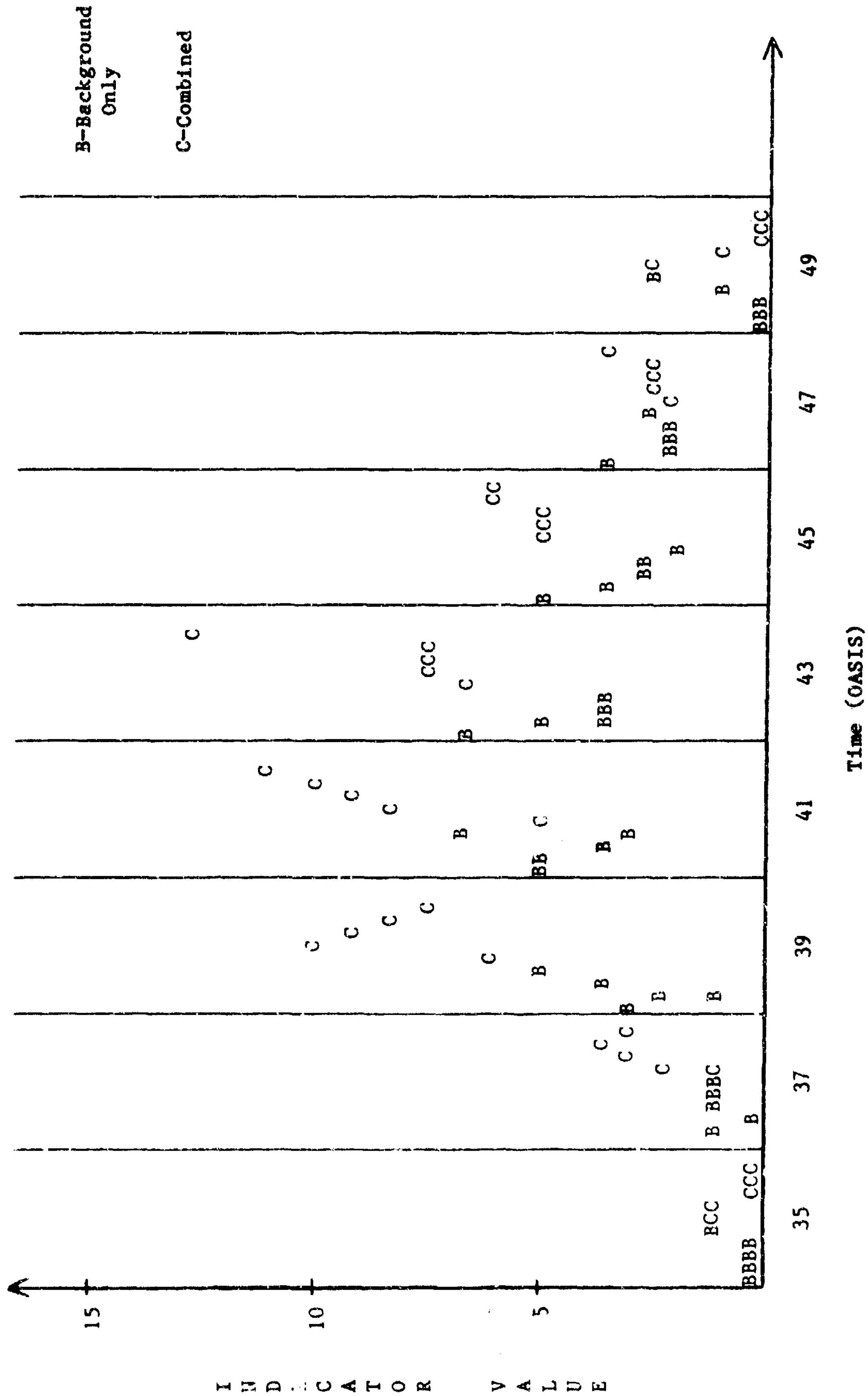
SCATTER PLOT-PEAK
(P_D=.90, 13 Targets, 30 Bomber Raid)



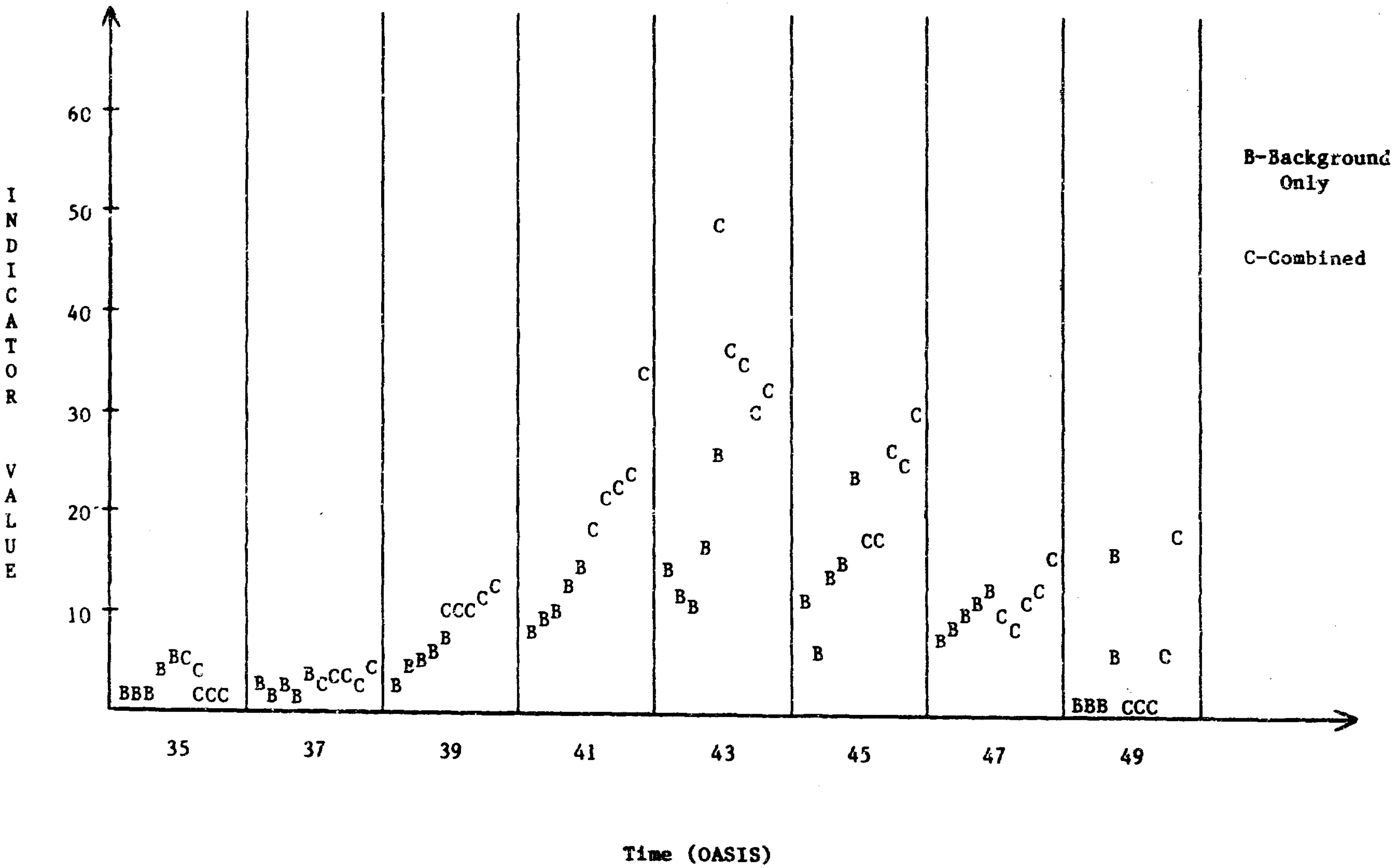

SCATTER PLOT-RIDGE
(P_D=.90, 13 Targets, 30 Bomber Raid)
B-Background Only
C-Combined
INDICATOR VALUE
10
20
30
40
50
60
35
37
39
41
43
45
47
49
Time (OASIS)

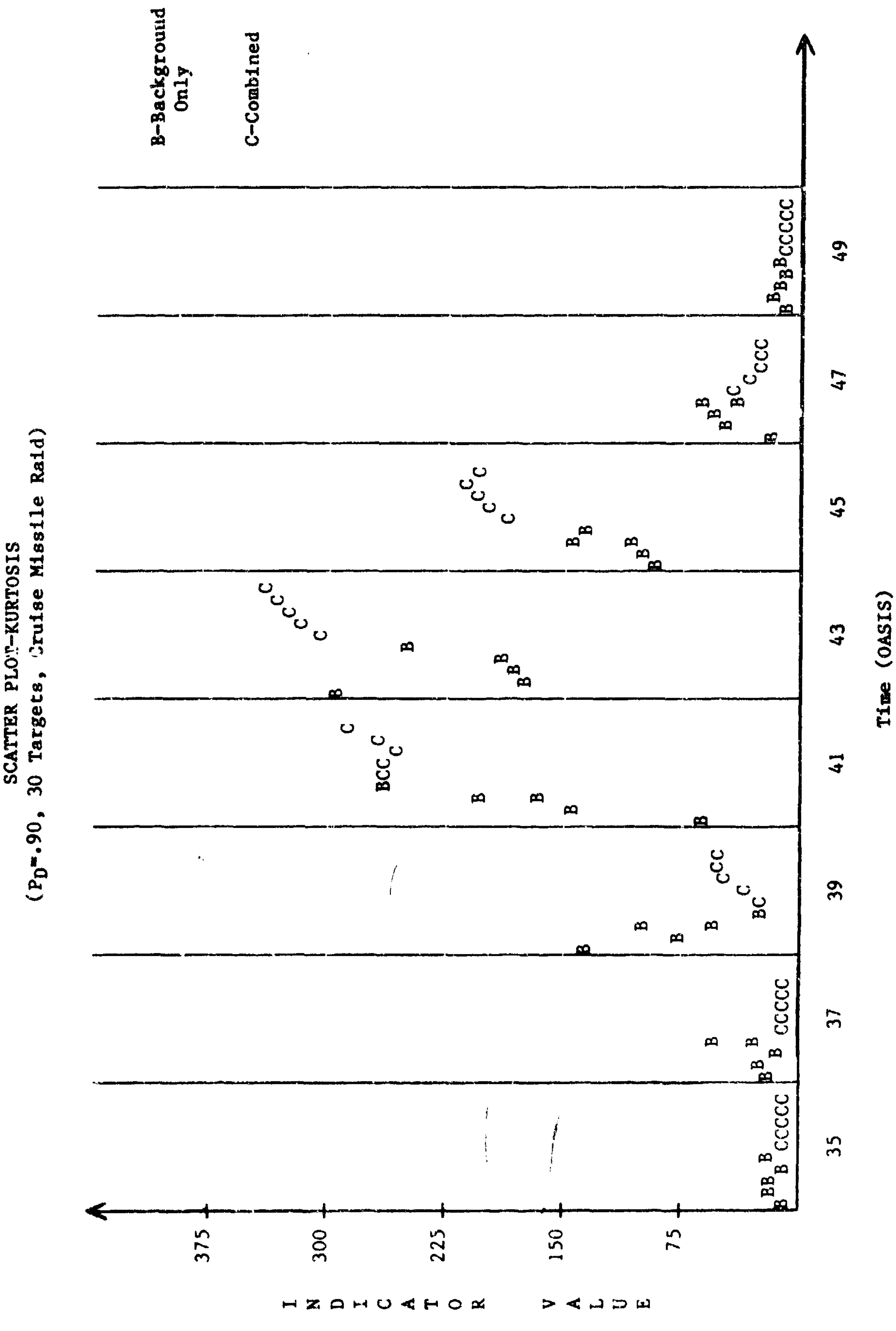

SCATTER PLOT-KURTOSIS
(P_D=.50, 13 Targets, 30 Bomber Raid)
B-Background Only
C-Combined
INDICATOR VALUE
200
100
35
37
39
41
43
45
47
49
Time (OASIS)

SCATTER PLOT-PEAK
(P_D=.50, 13 Targets, 30 Bomber Raid)

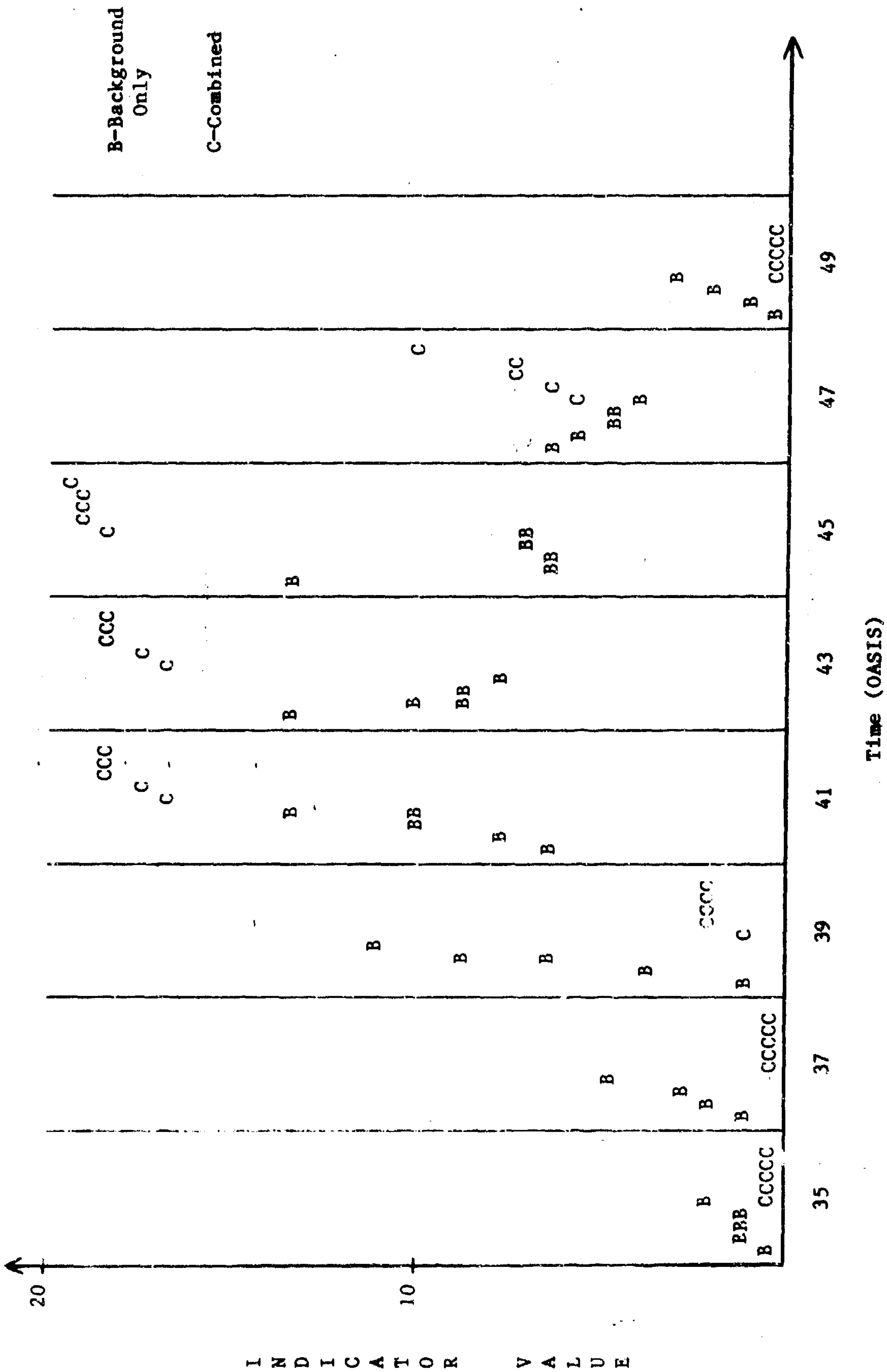


SCATTER PLOT-RIDGE
(P_D=.50, 13 Targets, 30 Bomber Raid)

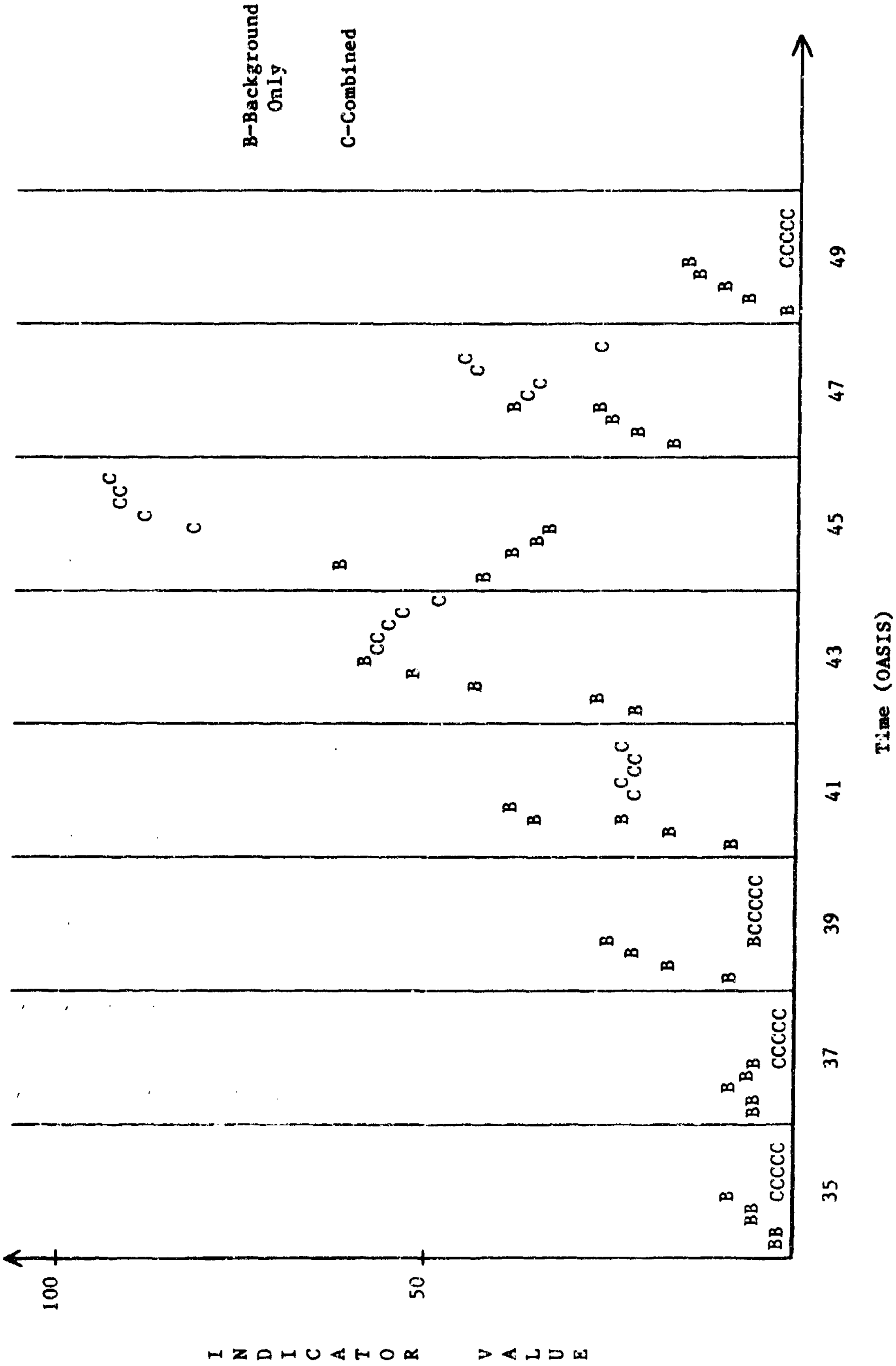



SCATTER PLOT-KURTOSIS
(P_D=.90, 30 Targets, Cruise Missile Raid)
B-Background Only
C-Combined
INDICATOR VALUE
375
300
225
150
75
35
37
39
41
43
45
47
49
Time (OASIS)

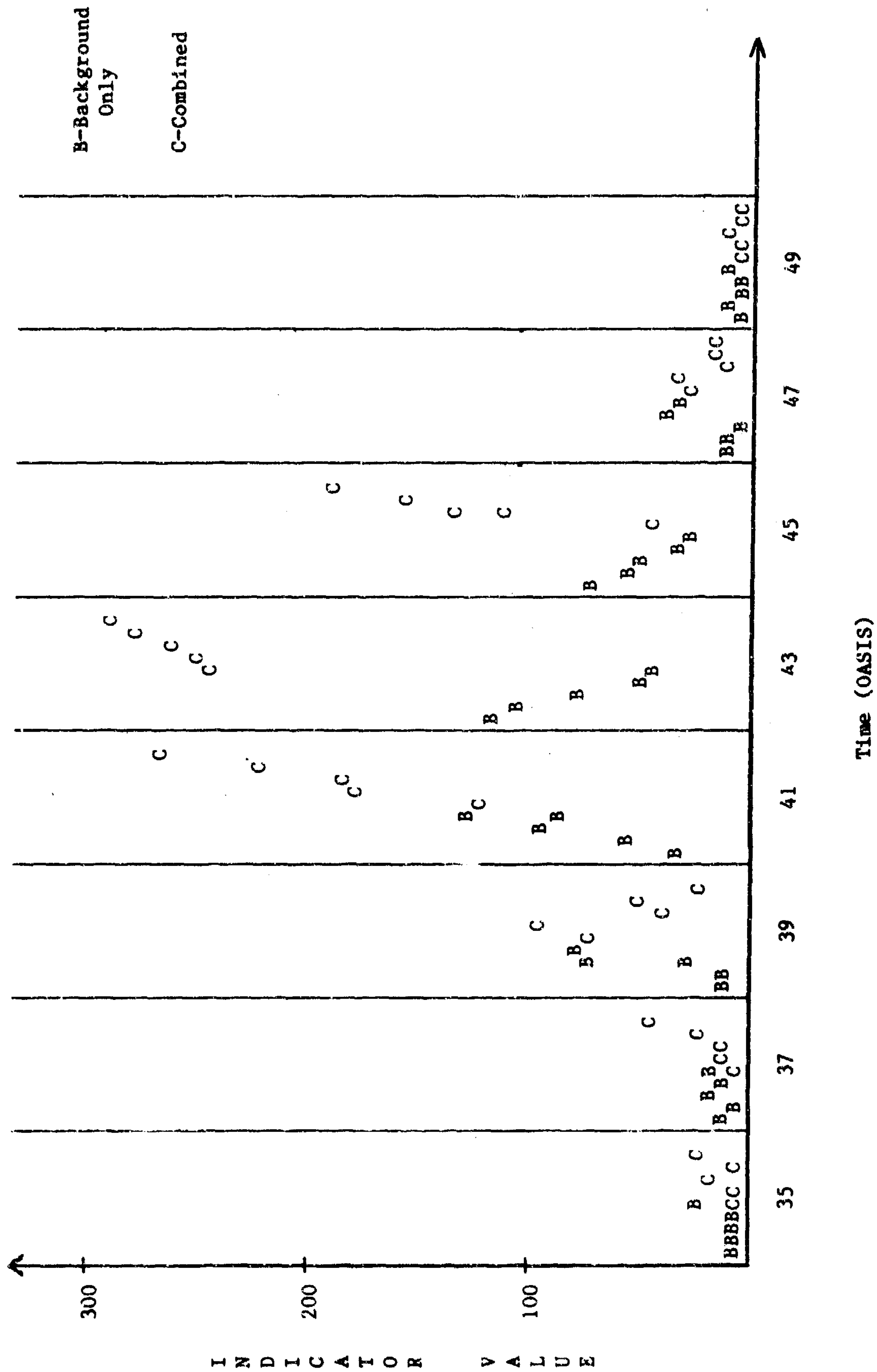
SCATTER PLOT-PEAK
(P_D=.90, 30 Targets, Cruise Missile Raid)



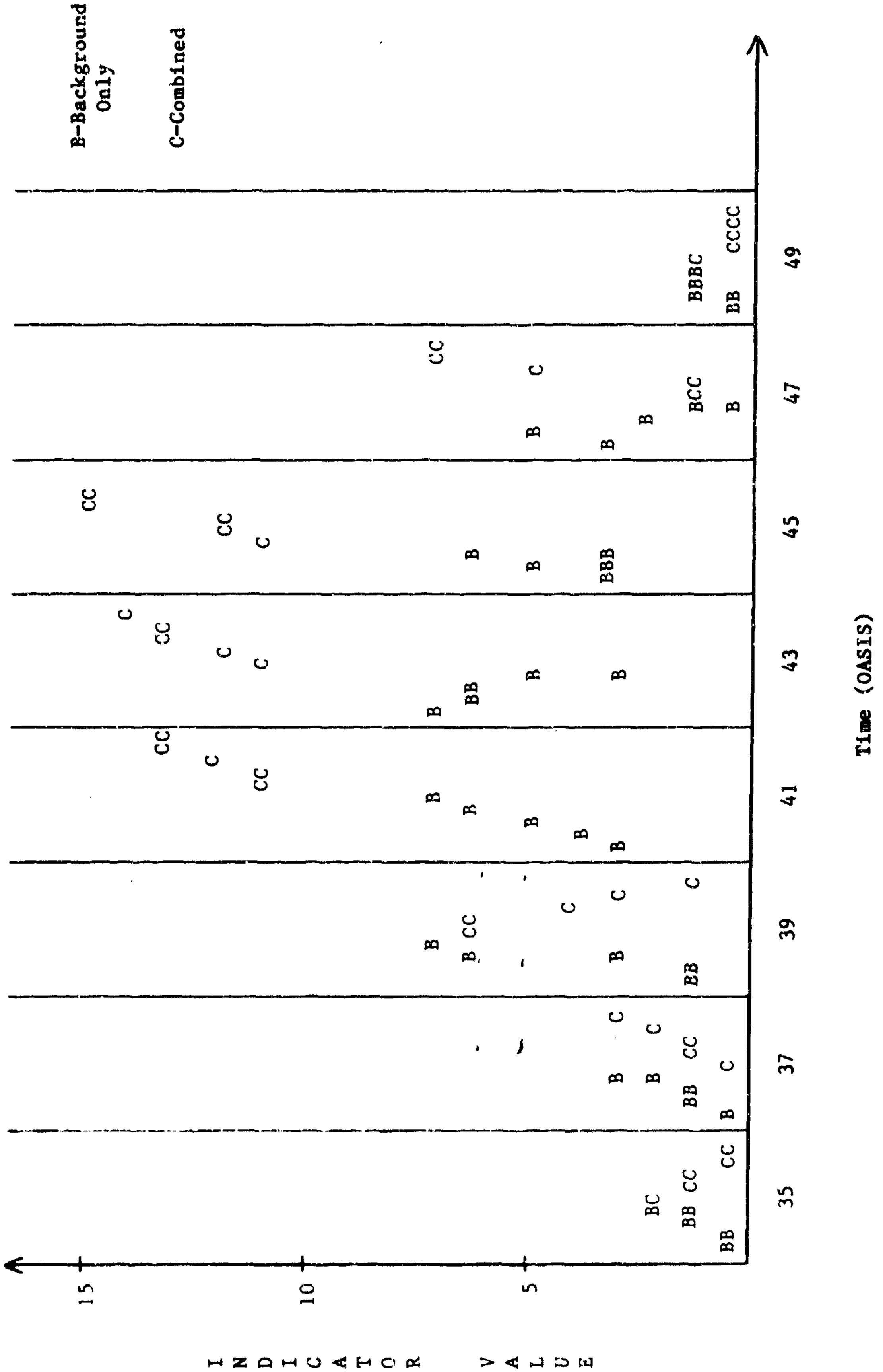
SCATTER PLOT-RIDGE
(P_D=.90, 30 Targets, Cruise Missile Raid)



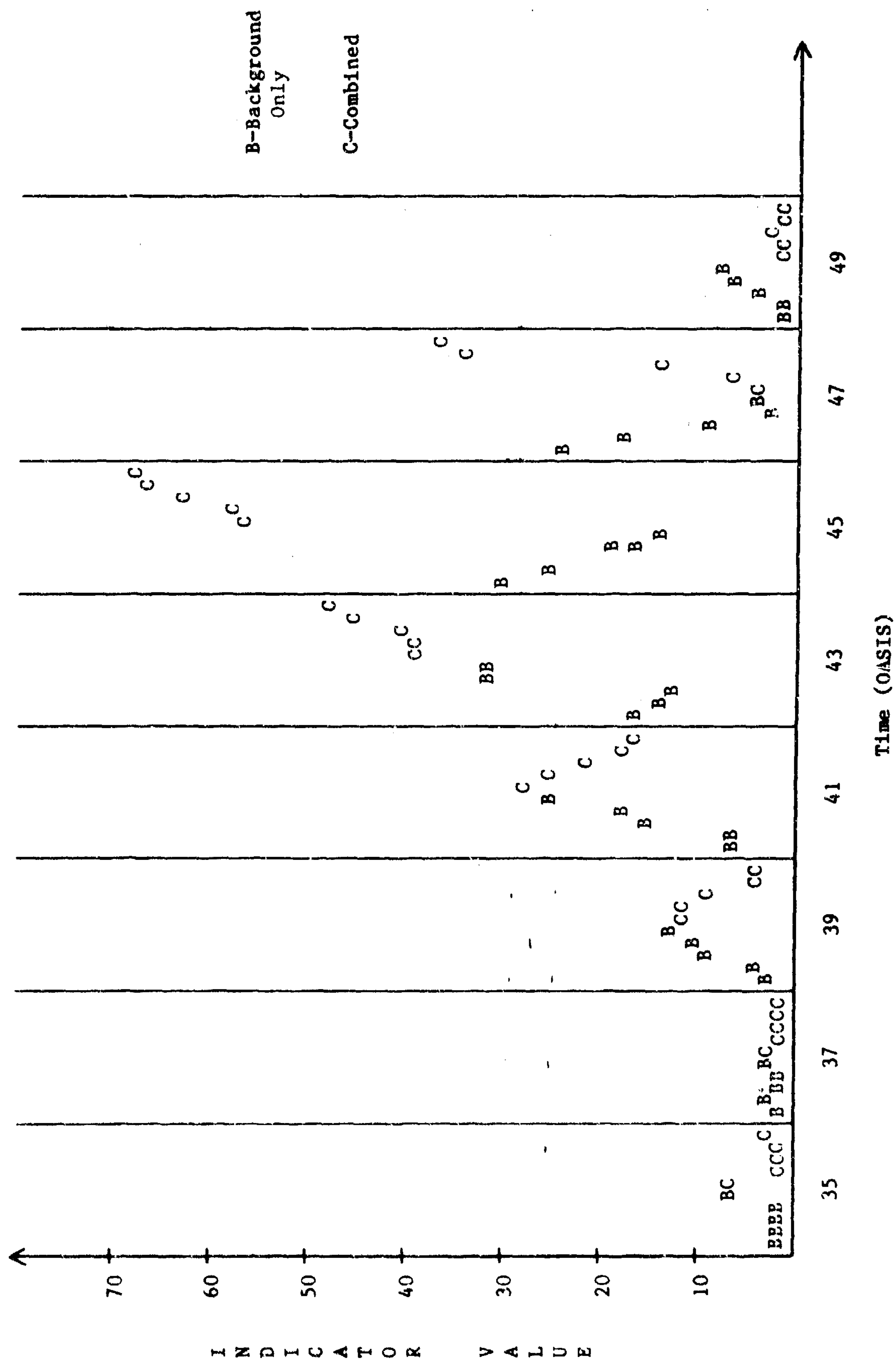
SCATTER PLOT-KURTOSIS
(P_D=.50, 30 Targets, Cruise Missile Raid)

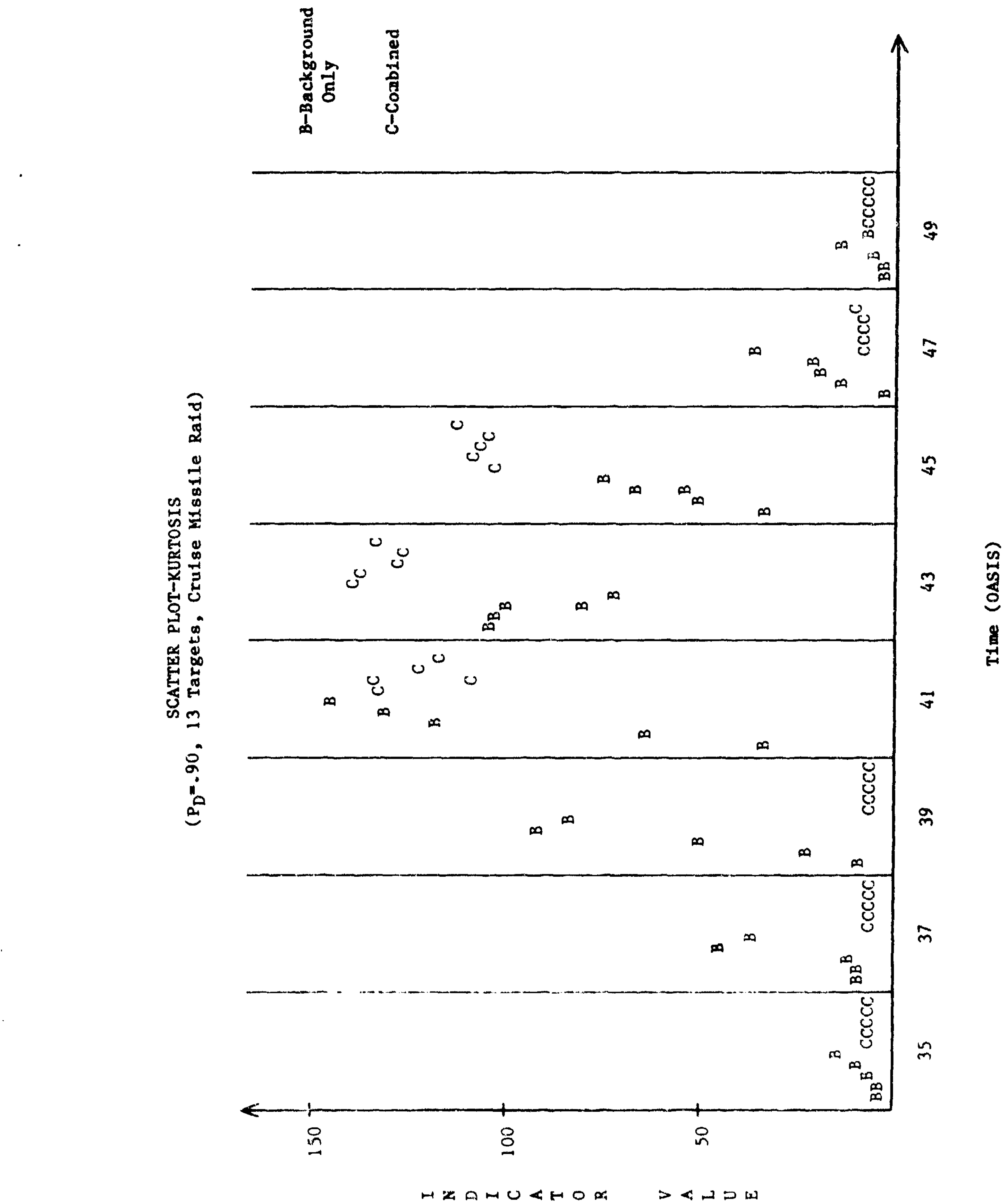


SCATTER PLOT-PEAK
(P_D=.50, 39 Targets, Cruise Missile Raid)

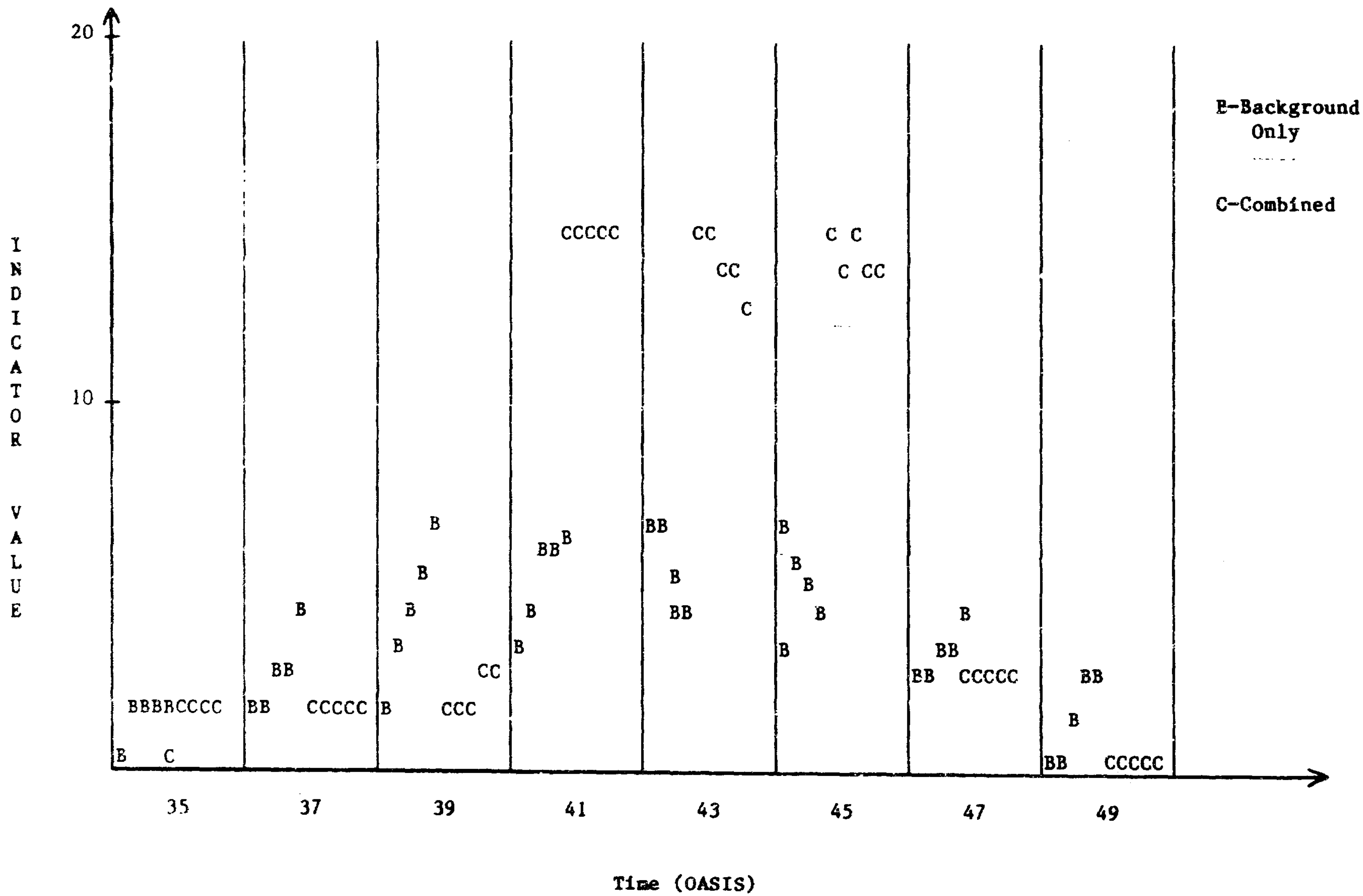


SCATTER PLOT-RIDGE
(P_D=.50, 30 Targets, Cruise Missile Raid)

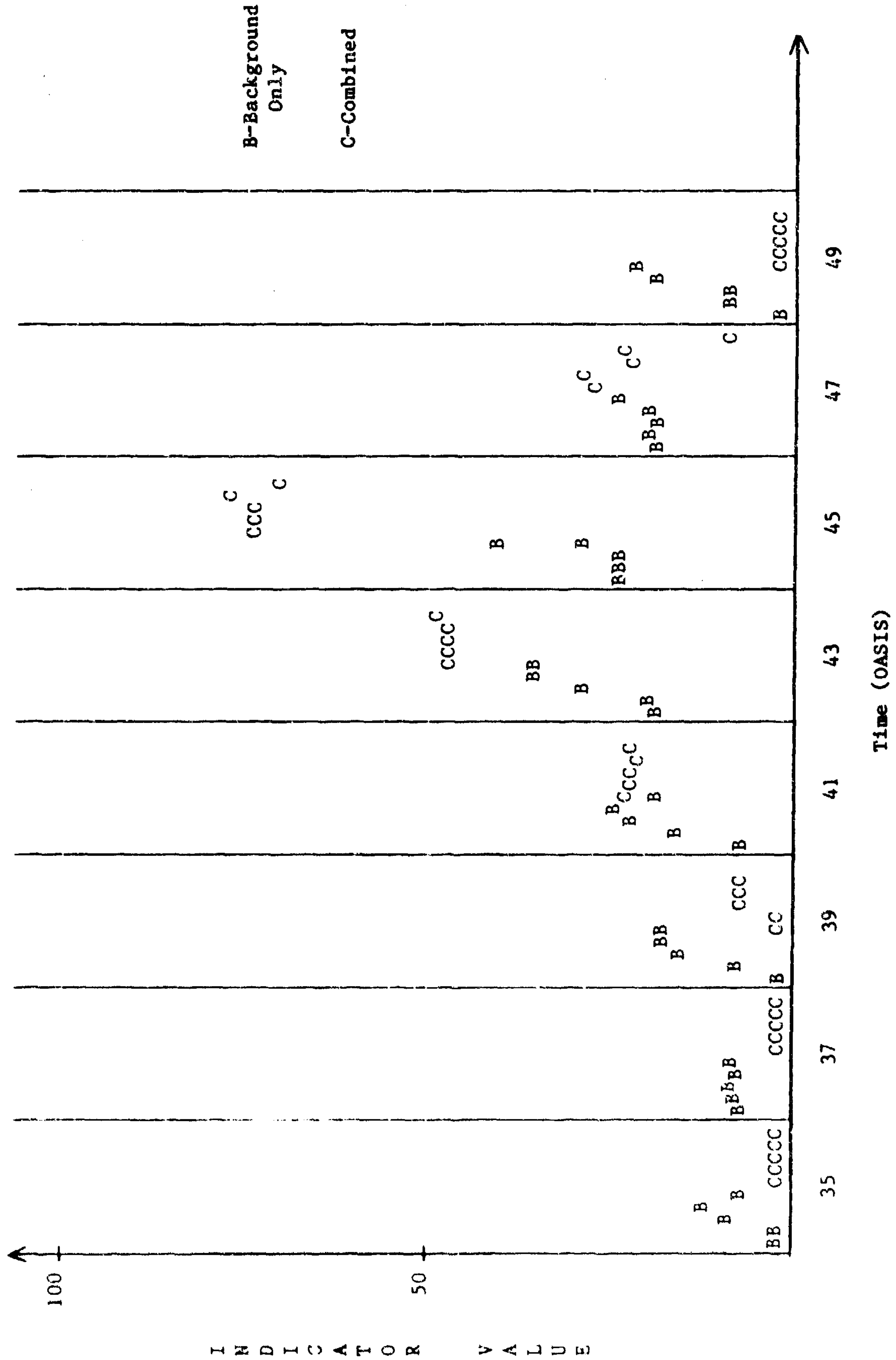


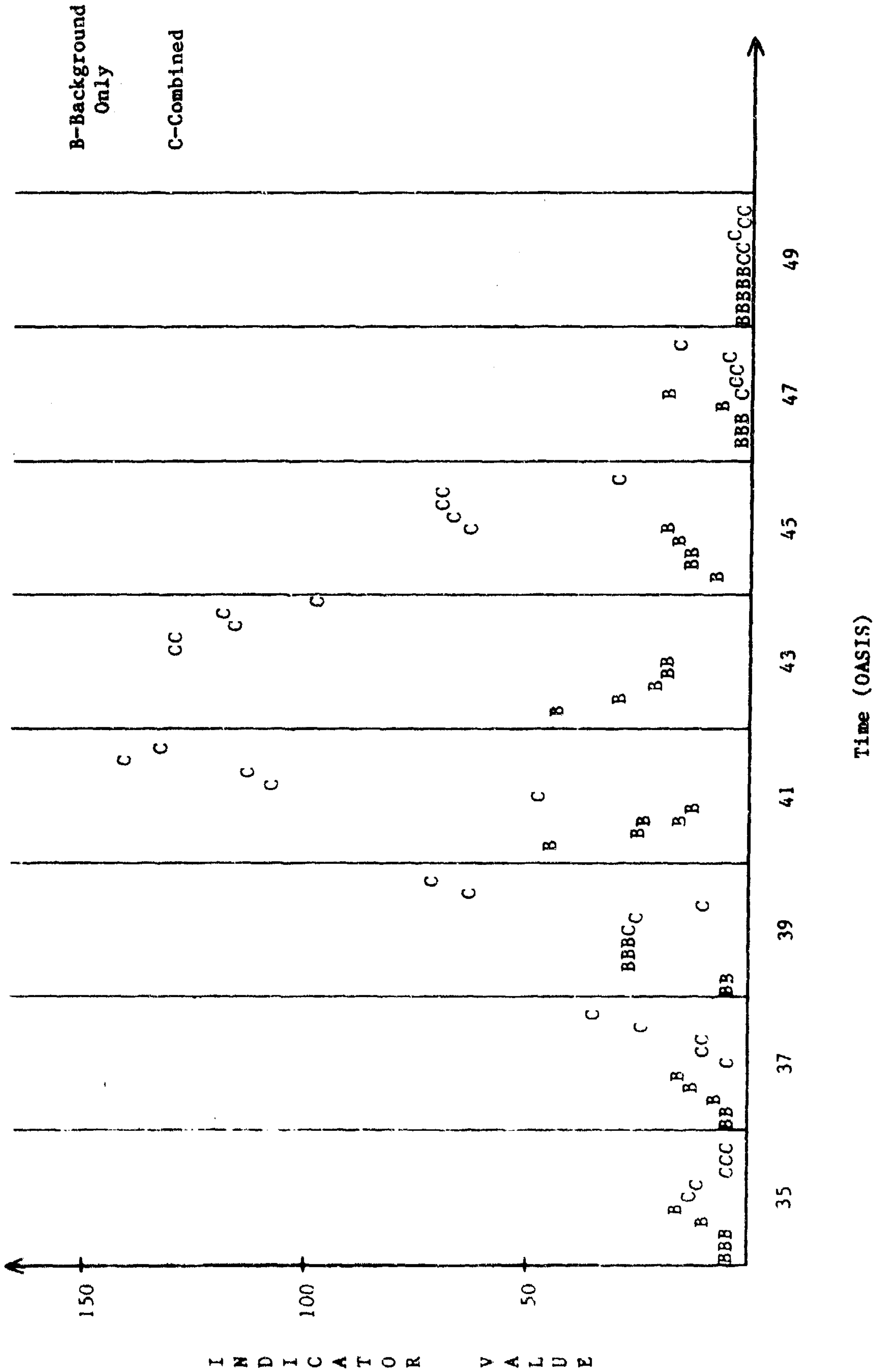

SCATTER PLOT-KURTOSIS
(P_D=.90, 13 Targets, Cruise Missile Raid)
B-Background Only
C-Combined
INDICATOR VALUE
150
100
50
35
37
39
41
43
45
47
49
Time (OASIS)

SCATTER PLOT-PEAK
(P_D=.90, 13 Targets, Cruise Missile Raid)

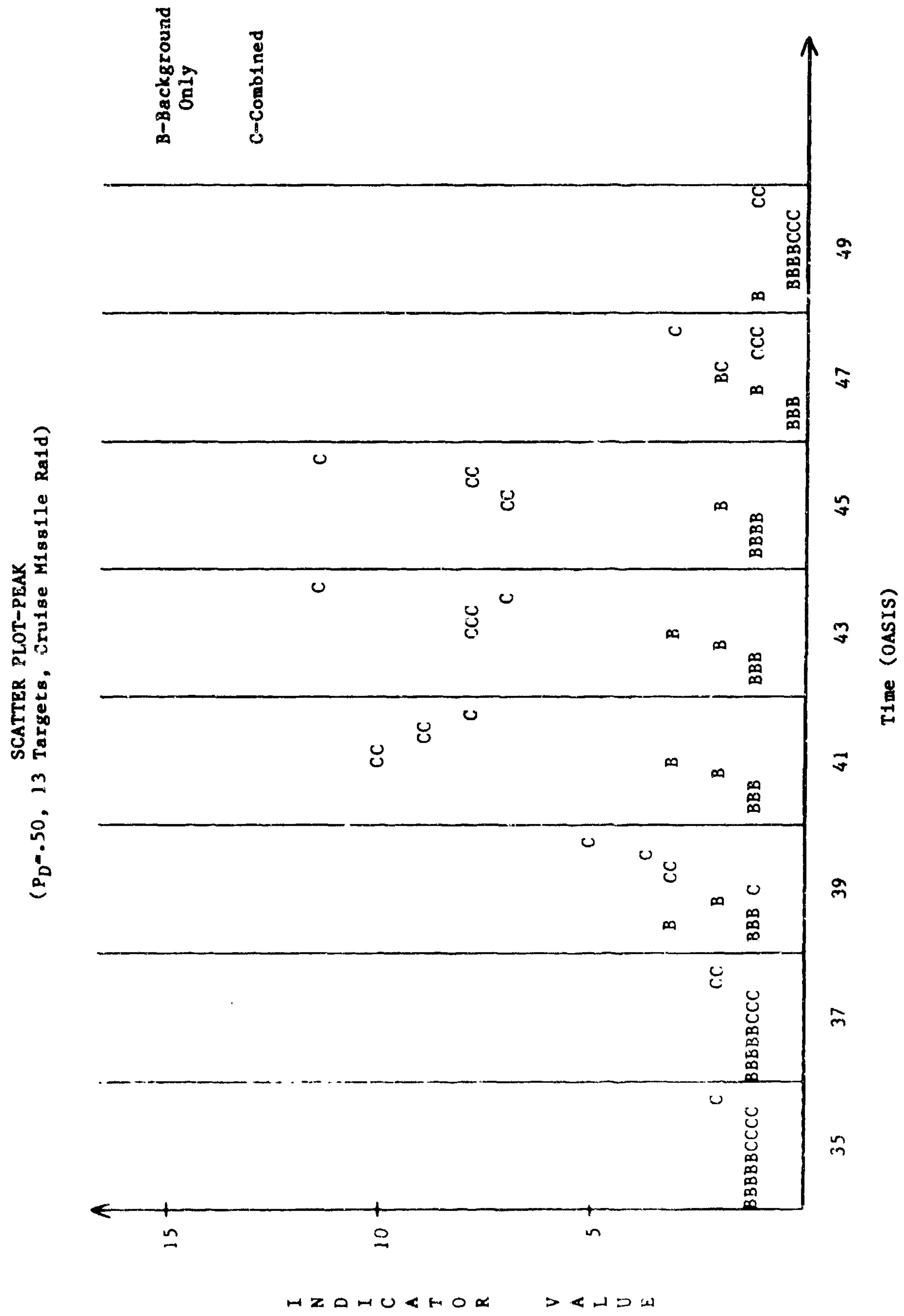


SCATTER PLOT-RIDGE
(P_D=.90, 13 Targets, Cruise Missile Raid)

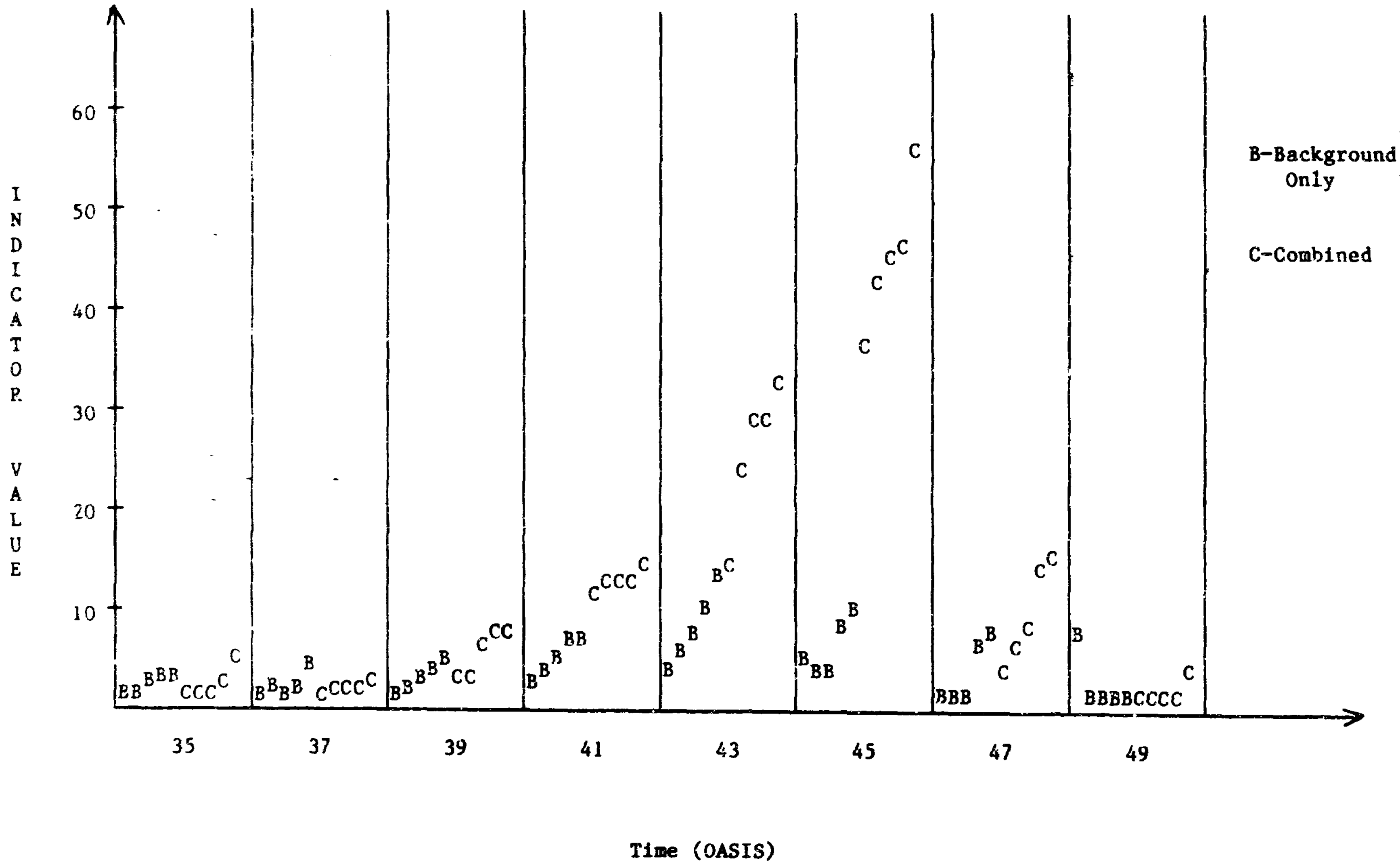




SCATTER PLOT-KURTOSIS
(P_D=.50, 13 Targets, Cruise Missile Raid)


SCATTER PLOT-PEAK
(P_D=.50, 13 Targets, Cruise Missile Raid)
B-Background Only
C-Combined
INDICATOR VALUE
15
10
5
35
37
39
41
43
45
47
49
Time (OASIS)

SCATTER PLOT-RIDGE
(P_D=.50, 13 Targets, Cruise Missile Raid)



APPENDIX B

OTHB and NWS Radar Coverage

OTHB and NWS Radar Coverage

Figure 19 depicts the OTHB and NWS radar cover of North America simulated for this report. The OTHB radar system which covers both the east and west coasts can initially "detect" an object at a range of 1700 nautical miles (nm) and begins "tracking" at 1300 nm. Tracking continues until a range of 500 nm The simulation divides the OTHB radar cover into 7° sectors, and it is assumed that the radar has the ability to detect any object above ground level. The NWS only "detects" objects and does not perform any "tracking" functions. The initial detection range is 1480 nm, and the NWS continues to detect until a range of 1080 nm.

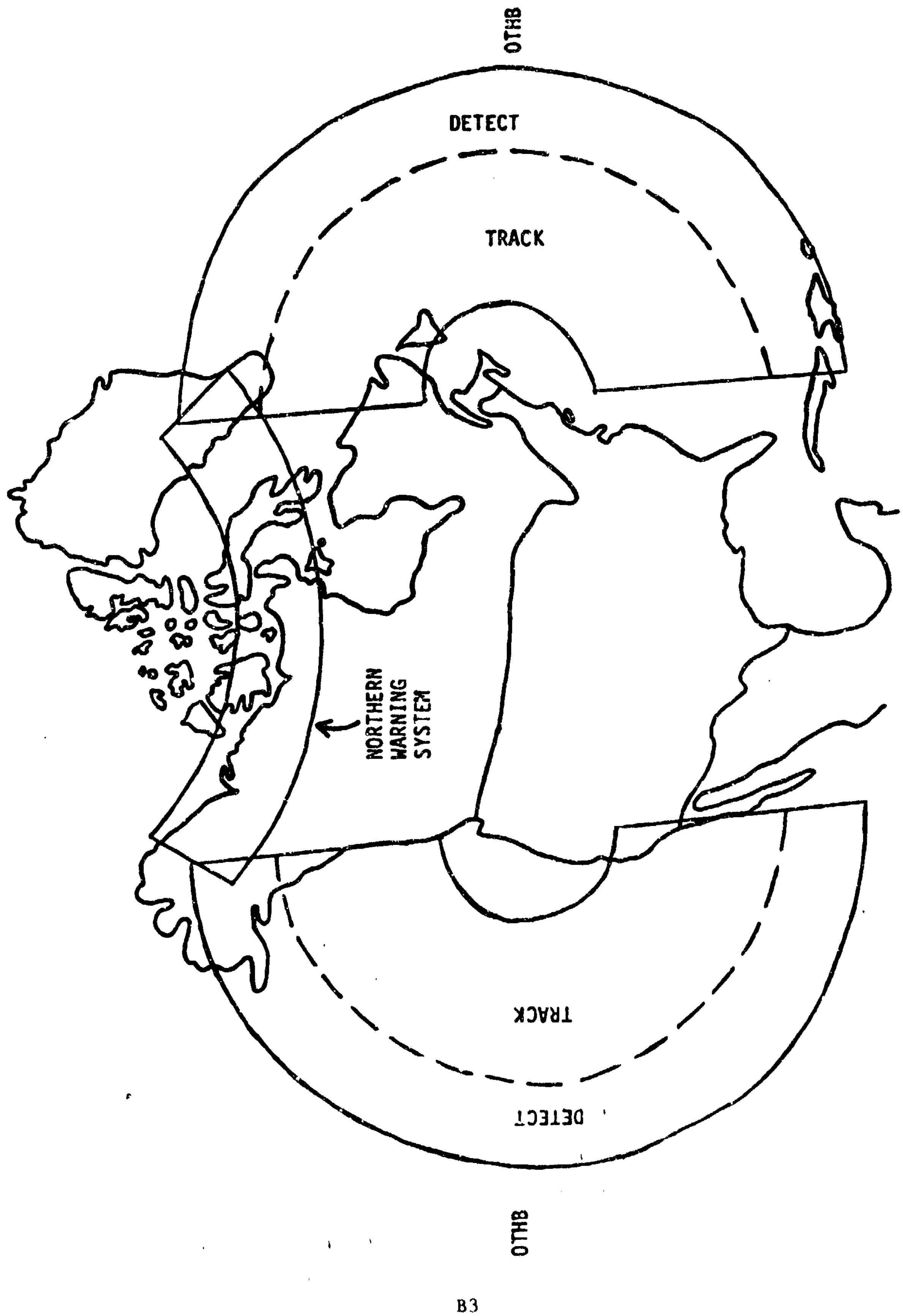


Figure 19
OTHB and NWS Radar Coverage

APPENDIX C

RIDGE Outlier Reexamined

RIDGE Outlier Reexamined

This appendix reexamines the RIDGE indicator for the 30 target set/P_D = .90 scenario since as stated in the body of this report, it appears to be an outlier. Figure 20 provides a worst case summary for an additional five runs of this scenario, where the triads represent OASIS time, maximum background height, and minimum value of the combined height, respectively. As was the case with the outlier, KURTOSIS and RIDGE have problems discriminating commercial traffic and an actual raid at time 41. By time 43, however, this problem has all but disappeared.

Examining Figure 21 provides further insight into the problems realized in Figure 20. The values in Figure 21 are percent of raids not detected if false alarm is our major concern, and percent of false alarms if detecting an immenent raid has a higher priority, respectively. The difficulty KURTOSIS and RIDGE have in both detecting a raid and reporting a false alarm at time 41, is rectified by 4300 hours. At this time, RIDGE has only a 20% chance of not detecting a raid when false alarm is of prime concern and never registers a false alarm when raid detection is of ultimate importance. Based upon these additional five runs, it appears that the RIDGE values from the first simulation was, indeed, an outlier.

TARGETS	30	30
P_D	.90	.90
KURTOSIS	43/260-263	41/266-228
PEAK	43/11-14	41/11-14
RIDGE	43/45-45	41/26-17

Figure 20
Summary Diagram
(RIDGE Outlier)

TIME	TARGETS	30
	P_D	.90
	KURTOSIS	0-0
4300	PEAK	0-0
	RIDGE	20-0
	KURTOSIS	100-20
4100	PEAK	0-0
	RIDGE	100-80

Figure 21
Reaction Thresholds
(RIDGE Outlier)